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THE THREE KINGDOMS OF NATURE,

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THE THREE KINGDOMS OF NATURE

BRIEFLY DESCRIBED.

BY THE

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WITH TWO HUNDRED AND THIRTY ILLUSTRATIONS,

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P R E F A C E.

THE faculties of our minds are developed in succession, as we advance in age, each of them reaching its maximum, and then gradually diminishing. In childhood, the senses acquire their greatest developement; in boyhood and youth, the memory and imagination; in early manhood the purely reasoning faculties; and in adult life, the judgement.

A rational system of education should be guided by the physiological law here laid down. The child should be instructed mainly through his sensations; the boy should learn Languages, ancient and modern, and Natural History, so far as it depends on observation; the youth should cultivate Mathematics and Logics; while studies, such as Ethics, Physiology, and Politics, should be reserved for the more mature period of life, in which the judgement corrects the rash conclusions founded on mere memory and reason.

Considered from the foregoing point of view, the neglect of Natural History, as a school study, appears most unaccountable, as it is inferior to no other study—not even Language—as a means of cultivating the memory and observation.

One cause of this neglect is certainly the want of suitable books, and of teachers. An attempt is made in the following pages to supply one of these wants by means of a small book, adapted for school and self-instruction; and care has been taken to present the Three Kingdoms of Nature to the learner, with a due regard to their relative importance.

The Author takes this opportunity of thanking the Provost and Senior Fellows of Trinity College for their liberality in defraying the entire cost of the numerous woodcuts with which the book is illustrated.

TRINITY COLLEGE, DUBLIN,
December 24, 1868.

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ELEMENTS OF NATURAL HISTORY.

PART I. THE MINERAL KINGDOM.

“LAPIDES—Corpora congesta, nec viva nec sentientia.”

“*Regnum Lapideum* rude inhabitat interiora; a salibus in terris generatur; temere miscetur; casu modificatur.”—*Linnaeus*.

CHAPTER I.

CRYSTALLOGRAPHY.

A MINERAL is an inorganic substance formed in the earth, possessing a definite geometrical shape, and a definite chemical composition. Rocks and stones are formed of minerals, sometimes quite pure, but more frequently mixed together in various proportions, from mechanical causes; minerals are the result of the chemical union of different bodies, while rocks, for the most part, are the product of various physical causes; hence the study of Mineralogy must precede that of Physical Geology, which explains the mode of production of the various rock masses of which the surface of the globe is composed.

Let us take for example a piece of *calc spar*, and a piece of *slate*; the *calc spar* is called a mineral, because it is generally

found crystallized in certain definite shapes, and never in any others, and to have the following definite chemical composition :—

Carbonic Acid,	44 per cent.
Lime,	56 „
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	100
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The piece of slate, on the other hand, although it presents a certain structure called *cleavage*, by reason of which it can readily be split into thin plates, shows no tendency to assume any definite crystalline shape; and although, on chemical analysis, it may be found to have a definite composition, through large tracts of country, yet this is found to be the result of the homogeneity of the fine mud of which it was originally composed, by mechanical deposition from water, and is in no respect due to the definite results of chemical combinations. Thus, the average composition of roofing slate may be—

Silica,	60.5 per cent.
Alumina,	19.7
Protoxide of Iron,	7.8
Lime,	1.1
Magnesia,	2.2
Potash,	3.2
Soda,	2.2
Water,	3.3
	<hr/>
	100.0
	<hr/>

Each of the constituents here named, silica, alumina, &c., are themselves the result of definite chemical combinations, and some of them are minerals found in nature; yet they are not combined together in a definite manner to form the compound called *roofing slate*; they are present as constituents of several minerals quite distinct from each other, but which happen, in the case considered, to be mixed up accidentally in various proportions by the mechanical action of running water, which has deposited the whole mixture originally in the form of fine mud.

The first subject to be considered in Mineralogy is, therefore, the geometrical forms of minerals, and this branch of the subject is generally called Crystallography.

Crystals are geometrical solids, bounded by planes, which are related to each other by definite laws that are never departed from. All the crystals found in natural or artificial compounds are reducible to the following seven groups, which are called crystalline systems :—

1. The Monometric system.
2. The Dimetric system.
3. The Trimetric system.
4. The Monoclinic system.
5. The Diclinic system.
6. The Triclinic system.
7. The Hexagonal system.

These systems are classified as follows :—

- | | | |
|--|---|---|
| A. Referred to <i>three</i> axes making
<i>right</i> angles with each other. | { | 1. <i>Monometric</i> —three axes equal.
2. <i>Dimetric</i> —two axes equal.
3. <i>Trimetric</i> —axes unequal. |
| B. Referred to <i>three</i> axes making
one or more <i>acute</i> angles with
each other. | { | 4. <i>Monoclinic</i> —one acute angle be-
tween axes.
5. <i>Diclinic</i> —two acute angles be-
tween axes.
6. <i>Triclinic</i> —three acute angles be-
tween axes. |
| C. Referred to the <i>three</i> diameters
of a regular hexagon, and to
a fourth axis drawn at their
point of intersection, perpen-
dicular to their plane. | { | 7. <i>Hexagonal</i> . |

1. **The Monometric System.**—It is proved by Euclid (xiii., 18, Scholium), that there are five solids, and five only, whose faces make equal angles with each other, and are bounded by regular figures. These are called the Regular Solids, and are all inscribable in a sphere. Their names are—

1. The Tetrahedron, or Four-faced Solid ;
2. The Hexahedron, or Six-faced Solid ;
3. The Octahedron, or Eight-faced Solid ;
4. The Dodecahedron, or Twelve-faced Solid ;
5. The Icosahedron, or Twenty-faced Solid.

The Tetrahedron, or Pyramid (Fig. 1.) has equilateral triangles for its faces, and is bounded by four such faces. The

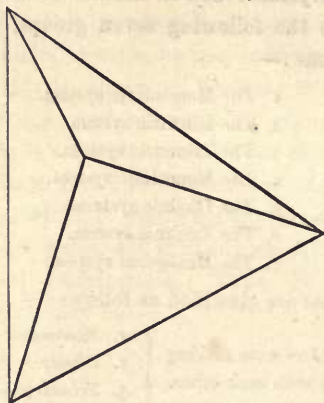


Fig. 1.

Tetrahedron has six edges, which make with each other the angles of an equilateral triangle.

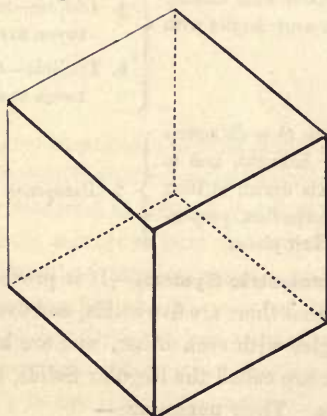


Fig. 2.

The Hexahedron, or Cube (Fig. 2), has squares for its faces,

and is bounded by six such faces. It has twelve edges which make right angles with each other.

The edges of the cube are parallel to the three monometric axes; and the relation between the Cube and Tetrahedron is best shown by means of (Fig. 3), which gives the construction of Euclid (xv., 1.)

“*To inscribe a Pyramid in a given Cube.*”—If the diameters of the cube were drawn ad' , bb' , cc' ; they would pierce the faces

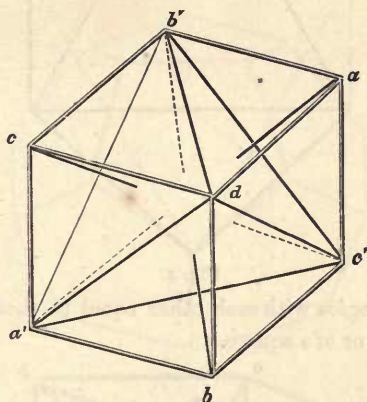


Fig. 3.

of the pyramid at right angles, and pass through their centres of gravity. The diameters of the cube are four in number, and are called the Tetrahedric axes, because they are perpendicular to the four faces of the inscribed tetrahedron. They are sometimes called the Octahedric axes, because they are also perpendicular to the faces of the inscribed octahedron.

The edges of the cube are called the Cubical, or monometric axes; and if they be assumed equal to unity, then the Tetrahedric axes, or diameters of the cube will be each represented by $\sqrt{3}$. The tetrahedric axes make each three angles with the

cubical axes, which are equal to each other, and to $70^{\circ} 32'$ nearly.*

The Octahedron (Fig. 4) has equilateral triangles for its faces, and is bounded by eight such faces; it has twelve edges,

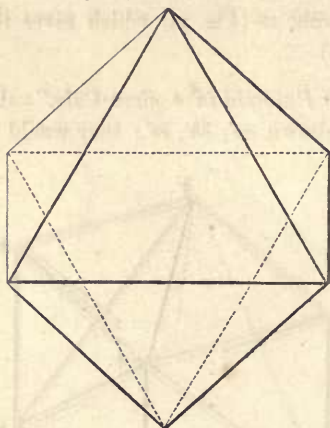


Fig. 4.

which make angles with each other equal to those of an equilateral triangle, or of a square.

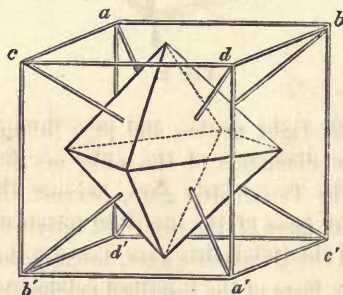


Fig. 5.

The relation between the Cube and the Octahedron is shown in Fig. 5, which gives the construction of Euclid (xv. 3.)

* The exact angle is given by the relation $\text{Secant } \phi = \sqrt{3}$.

“*To inscribe an Octahedron in a given Cube.*”—The four diameters of the cube aa' , bb' , cc' , dd' , pierce the faces of the octahedron at right angles, and pass through their centres of gravity. The propriety of the term octahedric axes is apparent from the construction.

The Pentagonal Dodecahedron, Fig. 6, has regular pentagons for its faces, and is bounded by twelve such faces; and has thirty edges, which make with each other the angles of a regular pentagon.

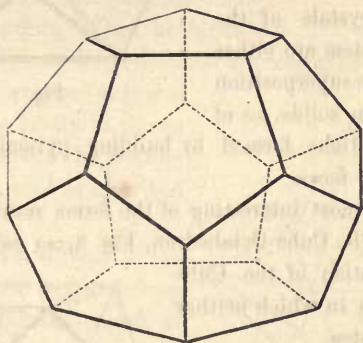


Fig. 6.

The Tetrahedron, the Cube, and the Octahedron, are found repeatedly in the mineral kingdom, and are combined with each other in infinite varieties; but it is remarkable that the Pentagonal Dodecahedron has not yet been discovered in the mineral kingdom, although some of its combinations with the other regular solids are well known. In like manner, the Icosahedron, or twenty-faced figure, has not yet been found, except in combination with the Octahedron. The Pentagonal Dodecahedron is met with in the solids formed by the mutual pressure of the cells of plants, and half the dodecahedron is known to occur in the cup-shaped calyces of some of the fossil Stone Lilies.

The Icosahedron, or twenty-faced figure, Fig. 7, has equilateral triangles for its faces, and is bounded by twenty such ; it has thirty edges, which make with each other the angles of the equilateral triangle or of the pentagon. Like the Dodecahedron, it occurs in minerals, only in combination with the other regular solids, and never simply by itself.

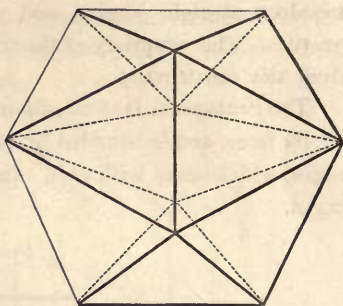


Fig. 7.

All the crystals of the Monometric system are either the result of the superposition of the Euclidean solids, or of simple combinations formed by building pyramids of regular form upon their faces.

One of the most interesting of the forms resulting from superposition, is the Cubo-Octahedron, Fig. 8, so called because it is the combination of the Cube and Octahedron in which neither solid predominates.

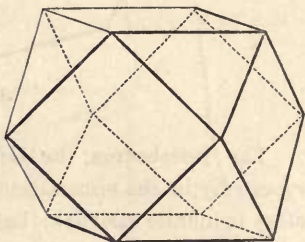


Fig. 8.

The *Cubo-Octahedron* is bounded by six squares and eight equilateral triangles ; it has twenty-four edges, which, like those of the Euclidean solids, are all equal to each other, and these edges make with each other angles which are equal to those of the equilateral triangle, the square, or the regular hexagon.

The Pyramidal modifications of the Euclidean solids are formed by building regular pyramids upon the faces of the primary solid ; and by comparing different forms of these solids with pyramids built upon their faces, several very interesting

relations between them become apparent, which could not otherwise have been perceived.

The *Pyramidal Cube* is shown in Fig. 9, and is formed by constructing four-faced pyramids upon the six faces of the primary Cube.

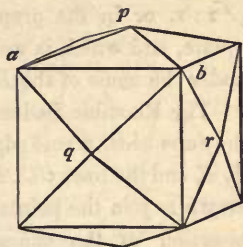


Fig. 9.

The *Pyramidal*, or *Three-faced Octahedron*, is shown in Fig. 10, and is formed by building up regular three-faced pyramids upon the eight faces of the primary Octahedron. When the Pyramidal Cube and Pyramidal Octahedron are compared with each other, they are to be supposed as placed in the relative positions shown in Fig. 5, in which the Octahedron is represented as inscribed in the cube.

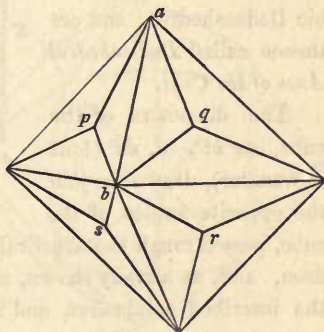


Fig. 10.

The number of faces in the Pyramidal Cube is found from the consideration that each of the four-faced pyramids, *p*, *q*, *r*, &c., is built upon one of the six faces of the primary cube, and hence the total number of faces of the pyramidal cube is $6 \times 4 = 24$.

In like manner, in the Pyramidal Octahedron, since each of the three-faced pyramids, *p*, *q*, *r*, *s*, &c., is built upon one of the eight faces of the primary Octahedron, the total number of faces must be $3 \times 8 = 24$.

If the pyramids *p*, *q*, *r*, &c., in the Cube, or the pyramids *p*, *q*, *r*, *s*, &c., in the Octahedron, were so constructed that the planes joining the vertices *p*, *q* of the pyramids with the intervening edge, *ab*, of the primary solid were to coincide, we

should have thus produced a remarkable solid, having twelve faces, each of which would be a rhombus, the ratio of whose diameters is $\sqrt{2} : 1$, or in the proportion of the diameter to the side of a square, and which is well known to mineralogists and naturalists under the name of the *Rhombic Dodecahedron*.

The Rhombic Dodecahedron is shown in Fig. 11, inscribed in the cube $abcd$, whose edges are bisected in the points C, B, G, D, E, F , and the lines $CC', BB', GG', DD', EE', &c.$ (six in number), drawn to join the points of bisection of the opposite edges of the faces of the cube, are perpendicular to the faces of the inscribed Rhombic Dodecahedron, and are thence called *Dodecahedral Axes of the Cube*.

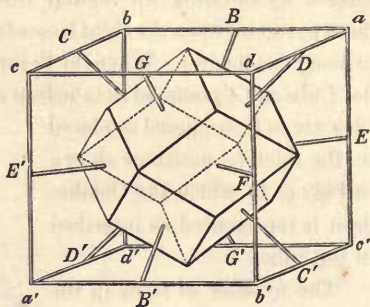


Fig. 11.

The diameters of the cube, $aa' bb', cc', dd'$ (four in number), drawn to join the opposite angles of the cube, pass through the trihedral angles of the Rhombic Dodecahedron, and, as already shown, are perpendicular to the faces of the inscribed octahedron and tetrahedron, being the tetrahedric or octahedric axes of the cube.

The Rhombic Dodecahedron forms the connecting link between the pyramidal cubes and octahedrons, just as the Cubo-octahedron forms the connecting link between the cube and octahedron. Its edges are all equal to each other, and its faces make equal angles, each angle being (120°) that of a regular hexagon. It occurs frequently in the mineral kingdom, and is well known to naturalists as the form assumed by the cell of the working bee, which is instructed to form it by a skill superior to its own.

If regular pyramids be built upon the faces of the Tetrahedron we obtain the *Pyramidal*, or *three-faced Tetrahedron*, shown in Fig. 12.

The pyramidal cubes, octahedrons, and tetrahedrons have faces formed of isosceles triangles, whose bases form the edges of the primary solid from which they are derived, and they may readily be recognized by this property.

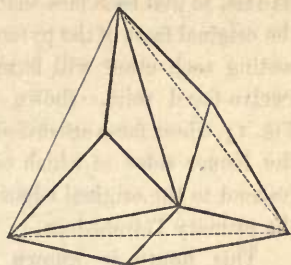


Fig. 12.

There is another class of modifications of the primary forms of Cube, Octahedron, and Tetrahedron, whose faces are formed of scalene triangles. These are known by the names, Six-faced Octahedron, Eight-faced Cube, and Six-faced Tetrahedron. The Six-faced Octahedron, or Eight-faced Cube is shown in Fig. 13, in which it is easy to recognize the primary forms both of the Cube and Octahedron, masked by the modifying planes.

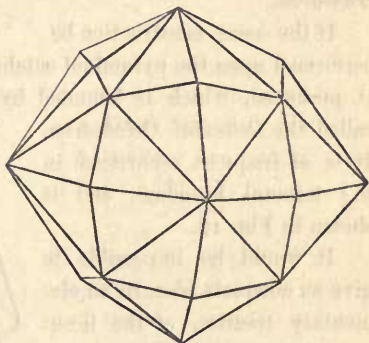


Fig. 13.

The Six-faced Tetrahedron is shown in Fig. 14, in which only one face is drawn, to prevent confusion in the figure.

A *Deltoid* is known in Geometry as a figure formed by two unequal isosceles triangles, constructed on opposite sides of the same base. There are two remarkable forms of crystals whose faces are *Deltoids*, and which are to be regarded as modifications of the Tetrahedron and Octahedron respectively.

If, having constructed pyramids, as shown in Fig. 12, upon

the faces of a Tetrahedron, we turn each of these pyramids round its axis, so that each face shall occupy a position halfway between the original faces of the pyramid—the faces of the pyramids intersecting each other will form a twelve-faced solid, shown in Fig. 15, whose faces are *deltoids*, the longer sides of which correspond to the original edges of the primary Tetrahedron.

This figure is known to crystallographers as the *Deltoid Dodecahedron*, or *Deltoidal Tetrahedron*.

If the same construction be performed upon the pyramidal octahedron, Fig. 10, another solid is produced, which is bounded by 24 deltoidal faces, and is called the *Deltoidal Octahedron*. It is of frequent occurrence in the mineral kingdom, and is shown in Fig. 16.

It would be impossible to give an adequate idea, in an elementary treatise, of the innumerable variety of forms of crystals produced by the combinations of these elementary forms

with each other, and the foregoing are selected as the most interesting of their class, because their faces are bounded by the simplest plane figures; squares, rhomboids, equilateral and isosceles triangles, or scalene triangles, symmetrically placed, and deltoids.

It may help the remembrance of these different crystallographical forms to associate them with the names of well-known mi-

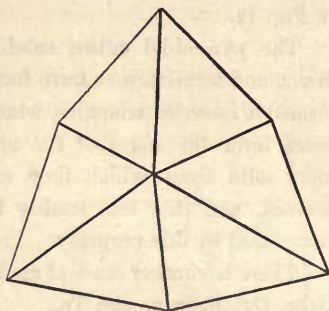


Fig. 14.

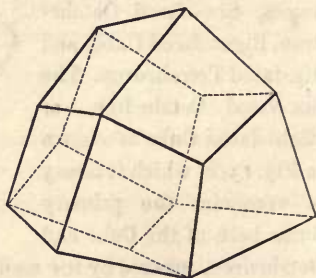


Fig. 15.

nerals which frequently assume them. This is done in the following table, which might readily be extended :—

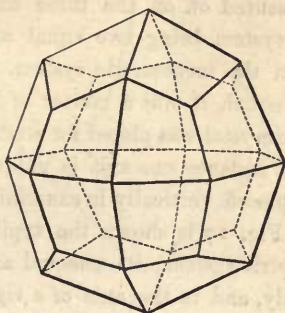


Fig. 16.

<i>Crystalline Form.</i>	<i>Mineral.</i>
I. Tetrahedron,	Grey Copper Ore, or Fahlerz.
II. Cube,	<div> { 1. Fluor Spar. 2. Galena. 3. Rock Salt. 4. Iron Pyrites. </div>
III. Octahedron,	<div> { 1. Alum. 2. Magnetic Oxide. 3. Spinelle. </div>
IV. Cubo-Octahedron,	Galena.
V. Pyramidal Cube,	<div> { 1. Native Copper. 2. Native Gold. </div>
VI. Pyramidal Octahedron,	<div> { 1. Galena. 2. Diamond. </div>
VII. Rhombic Dodecahedron,	Garnet.
VIII. Pyramidal Tetrahedron,	Grey Copper Ore.
IX. Six-faced Octahedron, or Eight-faced Cube,	<div> { 1. Diamond. 2. Garnet. </div>
X. Six-faced Tetrahedron,	Diamond.
XI. Deltoidal Tetrahedron,	Grey Copper Ore.
XII. Deltoidal Octahedron,	<div> { 1. Analeime. 2. Leucite. </div>

2. The Dimetric System.—In this Crystalline system, as in the Monometric and Trimetric systems, the axes of the crystal consist of three lines at right angles to each other, the portions measured off on the three axes in the Dimetric system being two equal and one unequal. In the monometric system, as all the axes were equal, it was a matter of indifference how the crystal was placed for study; but in the present instance one axis is unique, and is, therefore, placed vertically in examining the crystal. In Fig. 17 is shown the typical form of the dimetric system; its unequal axis is placed vertically, and is the axis of a right square prism, surmounted at each extremity by a half octahedron, the axis of which corresponds with the unequal axis of the system.

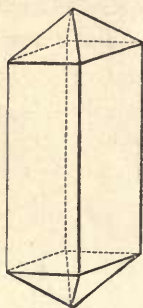


Fig. 17.

In the first system no reference is made to the lengths of the three axes, for they are all equal, and may be taken as unity. In the Dimetric system it is necessary to state the ratio of the unequal to the two equal axes; and this ratio is called the *parameter* of the Dimetric system.

If, in Fig. 17, we suppose the square prism to remain fixed, while the octahedron is turned round on its axis through half a right angle, we shall obtain the combination shown in Fig. 18. If the prism be turned through half a right angle, while the octahedron remains fixed, we shall obtain the combination shown in Fig. 19. And, finally, if two complete crystals, as in Fig. 17, composed of square prisms, with their half octahedrons attached, be superposed on each other, so as to allow a bevelment of the edges to take place, we shall obtain the form shown in Fig. 20, which is of frequent occurrence in the Dimetric system.

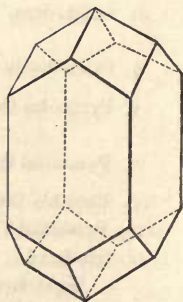


Fig. 18.

The octahedron of the Dimetric system has isosceles triangles for its faces, and the vertical angles of the isosceles triangles are

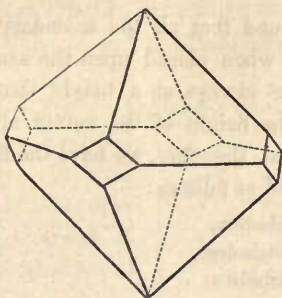


Fig. 19.

greater or less than the angles of an equilateral triangle, according as the vertex of the dimetric octahedron falls below or above the vertex of the regular octahedron of Euclid. The edges of the octahedron are of two kinds—eight terminal edges formed by the sides of the isosceles triangles, and four lateral edges, which form a square, and are the bases of the isosceles triangles.

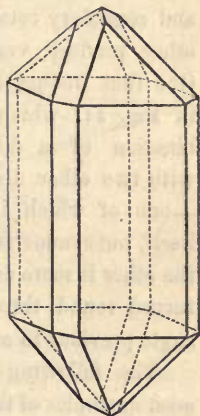


Fig. 20.

In the Monometric system there was only one octahedron, that of Euclid, which is inscribable in a sphere; in the Dimetric system there are an innumerable number of octahedrons, each with a square base, but differing from each other in the height of the vertex. It is found, however, that these octahedrons are related to each other in a very simple manner.

If p denote the parameter of the octahedron with the lowest vertex, its faces cut off lines on the three axes, which are respectively equal to

$$1 : 1 : p$$

and the diameters of this primary octahedron are double the preceding numbers, viz.:—

$$2 : 2 : 2p$$

It has been found that all the secondary octahedrons of the Dimetric system, when placed upon the same square as base, have their vertices always at a height that is double, triple, quadruple, &c., the height of the vertex of the primary octahedron. In general, therefore, we have the faces of the different octahedrons denoted as follows:—

First Octahedron,	1 : 1 : p
Second Octahedron,	1 : 1 : $2p$
Third Octahedron,	1 : 1 : $3p$
.
m^{th} Octahedron,	1 : 1 : mp

The combinations of the primary and secondary octahedrons with each other produce very elegant forms. One that frequently occurs is shown in Fig. 21, which shows the combination of a dimetric octahedron with two other dimetric octahedrons—one of which is less acute than itself, but symmetrically placed; while the other is more acute, and has been turned round through half a right angle previous to combination.

The following minerals furnish good examples of the Dimetric system of crystals:—

1. Tinstone.
2. Rutile.
3. Anatase.
4. Zircon.
5. Idocrase.
6. Apophyllite.

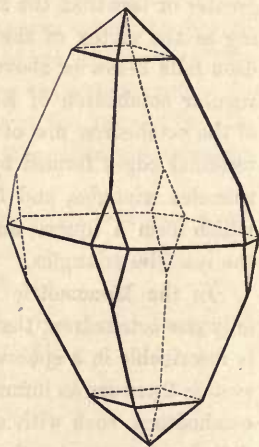


Fig. 21.

3. **The Trimetric System.**—In this system, the axes, as before, are at right angles with each other, but their lengths are all unequal, so that there are two parameters in the system which express the ratios of the second and third axes, respectively, to the first.

The accompanying Fig. 22 shows the primary octahedron of the Trimetric system inscribed in its primary prism. Its axes aa' , bb' , cc' , are equal to the edges of the prism, and intersect at right angles. The octahedron of the Trimetric system has, therefore, scalene triangles for its faces, and is constructed upon rhombic bases. Secondary octahedrons are met with in this system as well as in the Dimetric system. If p and q denote the parameters of the system, or ratios of the second and third axes to the first; the primary octahedron cuts off lengths on the axes equal to—

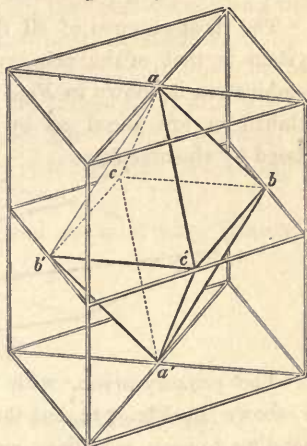


Fig. 22.

and its diameters are—

$$1 : p : q$$

$$2 : 2p : 2q$$

In the *Dimetric* system, the secondary octahedrons were formed by taking integer multiples of the unique axis, and therefore only one set of secondary octahedrons existed: in the *Trimetric* system we may take integer multiples of any of the three axes, and use them to construct secondary octahedrons; we may therefore have any of the following octahedrons in combination with the primary or with each other:—

$$m : p : q$$

$$1 : mp : q$$

$$1 : p : mq$$

$$1 : mp : nq$$

C

In nature, very few secondary octahedrons are met with except the following :—

Primary,	. . . . .	1 : p : q
Secondary,	. . . . .	1 : p : $2q$
„	. . . . .	1 : p : $3q$
„	. . . . .	2 : $2p$: q
„	. . . . .	3 : $3p$: q

The most common of all the combinations in the *Trimetric* system is that of the primary octahedron and prism. Such a combination is shown in Fig. 23, in which the summits of the octahedron are sliced off by the faces of the prism, and replaced by rhombic faces.

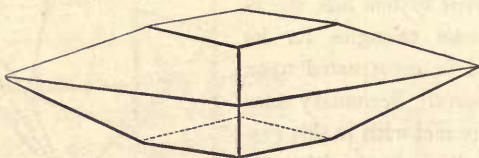


Fig. 23.

The primary prism, with its inscribed primary octahedron, is shown in Fig. 22; but there are secondary prisms corresponding to each secondary octahedron, formed by taking mul-

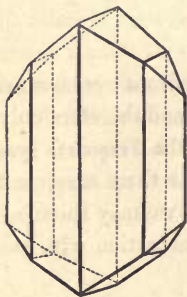


Fig. 24.

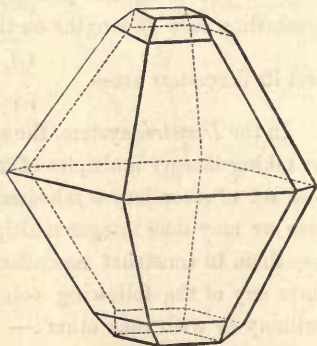


Fig. 25.

tiples of the axes along the diameters a, b, c . These prisms, when combined with each other, or with the various octahedrons, give

rise to many elegant forms of crystals. In Fig. 24 is shown the combination of two prisms parallel to one axis, with two prisms parallel to another axis; those of the third axis being absent.

In Fig. 25 is shown a combination of two octahedrons, primary and secondary, with terminal planes and a prism. The terminal planes slice the summits off both the octahedrons; and the prism bevels four of the edges of the primary octahedron.

The number of combinations possible from the union of the various octahedrons and prisms in the Trimetric system is very great, but they are easily recognized after a little practice, in consequence of the great symmetry of the system referred to its rectangular axes.

The following minerals furnish good examples of the Trimetric system of crystals:—

1. Aragonite.
2. Harmotome.
3. Stilbite.
4. Topaz.
5. Sulphate of Barytes (Heavy Spar).

4. The Monoclinic, Diclinc, and Triclinic Systems.—The Clinic systems differ from the Metric systems, in Crystallography, in this respect, that their axes contain one or more acute angles, while those of the Metric systems are always at right angles to each other. Thus, in the Metric systems, the greatest number of constants necessary to define the crystal is only two, viz., the *parameters* that express the ratios of the lengths of two of the axes to the third; but, in the Clinic systems, the number of constants ranges from three to five, in the following manner:—

1. Monoclinic System—Contains two parameters, and one acute angle.
2. Diclinc System—Contains two parameters, and two acute angles.
3. Triclinic System—Contains two parameters, and three acute angles.

In Fig. 26 I have shown the octahedron of the Clinic systems, inscribed in the prism of the same systems. The ratios of the axes aa' , bb' , cc' , to each other are, as before, the parameters of

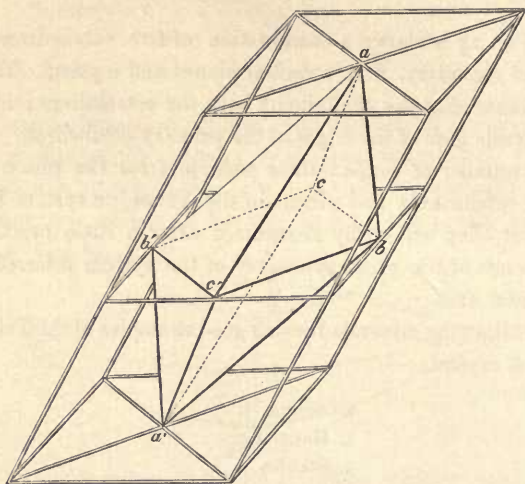


Fig. 26.

the system; and it is Monoclinic, Diclinc, or Triclinc, according as one, two, or three, of the angles made with each other, by aa' , bb' , cc' , are acute and not right.

There are secondary octahedrons and secondary prisms in the Clinic systems that modify each other, and produce combinations analogous to those described in the Trimetric system, but much more complex, and subjected to laws too difficult for examination in an elementary treatise.

The following minerals and salts afford examples of the crystals belonging to the Clinic systems:—

Monoclinic.

- | | |
|------------------------------------|-------------------------------|
| 1. Realgar (Sulphuret of Arsenic). | 6. Felspar. |
| 2. Carbonate of Soda. | 7. Spheue. |
| 3. Wolfram. | 8. Gypsum (Sulphate of Lime). |
| 4. Epidote. | 9. Sulphate of Iron. |
| 5. Augite. | |

Diclinic.

Naumann has discovered a Clinic system with only one right angle in certain artificial salts, and some crystallographers suppose that Felspar may be referred to this system.

Triclinic.

1. Labradorite.
2. Albite.
3. Anorthite.
4. Axinite.
5. Sulphate of Copper.

5. **The Hexagonal System.**—This system is referred to a regular hexagon as base, and its primary forms are the Hexagonal Dodecahedron, Fig. 27, and the Hexagonal Prism Fig. 28, which may be terminated by the Hexagonal Dodecahedron, or by flat summits. The form

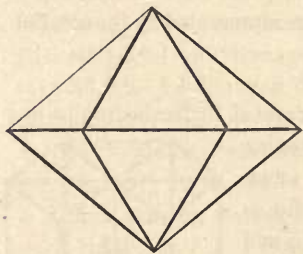


Fig. 27.

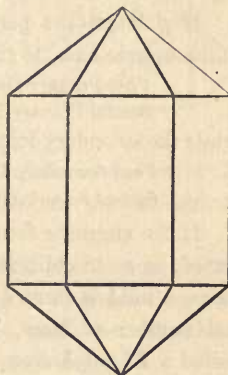


Fig. 28.

shown in Fig. 27 is often assumed by the mineral called Gmelinite, and Fig. 28 is a common form of Quartz: the flat terminations of the hexagonal prism are best shown by Apatite and Emerald.

The Hexagonal Dodecahedron has twelve faces, eighteen edges, and eight angles; the faces are isosceles triangles, and the edges are of two kinds—twelve terminal, forming the sides of the triangles; and six lateral, forming the bases of the same triangles.

If the hexagonal dodecahedron or prism be turned round its axis through half the angle of an equilateral triangle, and so combined with the original figure, it will produce a bipyramidal figure with twenty-four faces, called the *Didodecahedron*, or a prism with twelve faces instead of six faces. Both of these hexagonal dodecahedrons are regarded as primary, and they have the same relation to each other as the primary square prisms of the Dimetric system, which resembles the Hexagonal system in being referred to a unique axis.

Secondary dodecahedrons are frequently found to occur whose axes are multiples of the axis of the primary dodecahedron, and these secondary dodecahedrons may belong to either system of the primary dodecahedrons.

If p denote the parameter of the Hexagonal system, or ratio of the unique axis, to the horizontal or hexagonal axes, we have,

First Primary Dodecahedron, . . . $1 : 1 : \frac{1}{2} : p$

Second Primary Dodecahedron, . . . $2 : 1 : 2 : p$

while the secondary dodecahedrons are represented by the notation,

First Secondary Dodecahedron, . . . $1 : 1 : \frac{1}{2} : mp$

Second Secondary Dodecahedron, . . . $2 : 1 : 2 : mp$

If the alternate faces of the Hexagonal Dodecahedron be produced, so as to obliterate the intervening faces, a solid is formed of half the original number of faces, and this solid is called a *Rhombohedron*. In Figs. 29 and 30 I have shown the hexagonal dodecahedron, and its derived rhombohedron, inscribed in the primary hexagonal prism, so as to show the relation of the solids to each other. The axis AB is the axis of symmetry, and is also called the optic axis. Two different rhombohedrons may be formed out of the same hexagonal dodecahedron, for there are two distinct sets of alternate faces, either of which may be

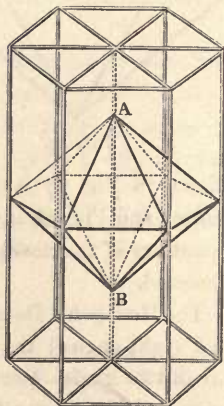


Fig. 29.

produced, and the two Rhombohedrons so formed have to each other a relation similar to that of the two primary Dodecahedrons.

The primary Dodecahedrons may be confounded by turning either of them through half the angle of an equilateral triangle; and the primary Rhombohedrons may be confounded by turning either of them through the angle of an equilateral triangle.

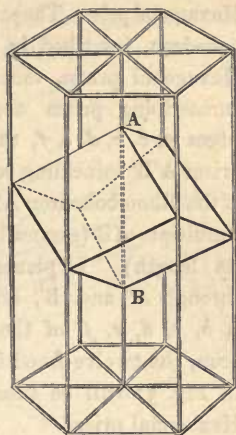


Fig. 30.

Many Crystallographers regard the Rhombohedron as the fundamental form of the Hexagonal system, named by them the Rhombohedric system; and the Hexagonal Dodecahedron is regarded by them as the result of the combination of the two primary Rhombohedrons. The relation between the Rhombohedron and Hexagonal Dodecahedron is similar to that between the Tetrahedron and Octahedron in the Monometric system, thus—

1. The Octahedron may be converted into one or other of two primary Tetrahedrons by producing its alternate faces; and the primary Tetrahedrons may be made to coincide by turning either of them through a right angle.
2. The Octahedron may be regarded as a figure produced by the superposition of two Tetrahedrons differing in position by a right angle.

In the preceding statements we may substitute the Hexagonal Dodecahedron for the Octahedron, and the Rhombohedron for the Tetrahedron, provided we at the same time substitute the angle of an equilateral triangle for that of a square.

A remarkable form of crystal, frequently occurring in calc

spar, called Dog-toothed Spar, is shown in Fig. 31, which exhibits its relation both to the primary Rhombohedron and to the primary Hexagonal prism. The primary Rhombohedron, inscribed in the primary Hexagonal prism, touches the circumscribing prism along the six edges a, b, c, d, e, f , the axis of the prism $A'B'$ coinciding with the axis of the Rhombohedron AB , and being a multiple of it (generally three times its length). If planes be drawn through A' and B' , and the edges a, b, c, d, e, f , of the Rhombohedron, the twelve-faced figure shown in Fig. 31 will be inscribed in the Hexagonal prism.

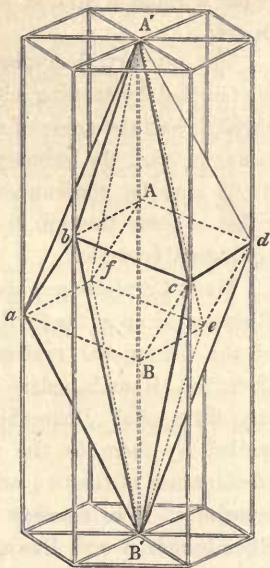


Fig. 31.

This remarkable form of crystal is commonly called the *Scalenohedron*, and is of frequent occurrence in the Hexagonal or Rhombohedric system. In the preceding investigation it has been deduced directly from the primary Rhombohedron; but it may be formed also from the Hexagonal Didodecahedron already described as formed by the combination of the two primary Hexagonal Dodecahedrons. If one half of the faces of the Didodecahedron be produced so as to obliterate the alternate faces, the result will be the Scalenohedron corresponding to the secondary Didodecahedron selected for experiment; and if the axis of this Didodecahedron be three times the axis of the primary Hexagonal Dodecahedron, or Rhombohedron, the Scalenohedron so formed will be the well-known Dog-toothed Calc Spar Crystal.

The combinations of forms occurring in the Hexagonal sys-

tem are almost endless, some hundreds being described in Calc Spar alone. Two of the most common are exhibited in Figs. 32 and 33.

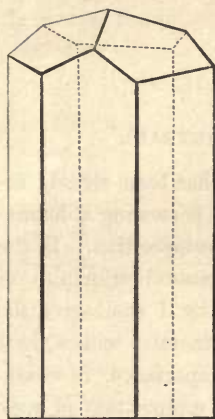


Fig. 32.

In Fig. 32 is shown the combination of the Hexagonal prism with the Rhombo-

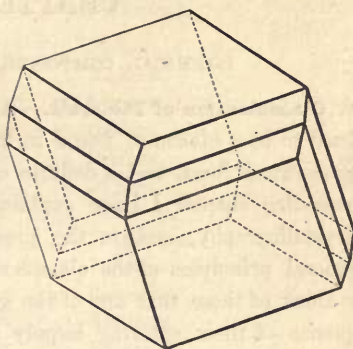


Fig. 33.

hedron, commonly called Nail-head Spar; and in Fig. 33 is shown the combination of the Rhombohedron with the Scalenohedron.

The following minerals present good examples of crystals occurring in the Hexagonal system:—

1. Calc Spar.
2. Quartz.
3. Apatite.
4. Beryl.
5. Chabasite, or Gmelinite.
6. Corundum.
7. Tourmaline.

CHAPTER II.

CHEMICAL COMPOSITION OF MINERALS.

1. Classification of Minerals.—A mineral has been already defined to be a substance found in the earth, possessing a definite geometrical form, and a definite chemical composition. In the preceding chapter I have explained the general principles of Crystallography, and in the present chapter I shall give the general principles of the classification of minerals, with a short account of those that are of the greatest importance, in consequence of their entering largely into the composition of rock masses. The following classification embraces all known minerals in five divisions:—

1. Oxygen Compounds.
2. Fluorides and Chlorides.
3. Sulphurets and Arseniurets.
4. Native Elements.
5. Organic Compounds.

This classification is based essentially on the Chemical composition of minerals, and may be readily understood without entering into details, from the following considerations:—The examination of the different substances that compose the surface of the earth has led Chemists to admit the existence of sixty-four distinct elements, which cannot be further reduced; and it may be added, as an interesting fact, that the chemical examination of meteoric stones (which are supposed to reach the earth from the interplanetary spaces) has not led to the discovery of any element in addition to the sixty-four Telluric elements already known. It has been proved by chemists that each of the elements, in

combining with the others, does so in the proportion of certain numbers (or multiples of those numbers), which are called equivalent numbers, or Atomic Weights. The following table contains the names of the sixty-four elements and their Atomic Weights:—

Atomic Weights of the Elements.

1. Aluminium,	13 $\frac{3}{4}$	33. Nickel,	29 $\frac{1}{2}$
2. Antimony,	122	34. Niobium,	<i>x</i>
3. Arsenic,	75	35. Nitrogen,	14
4. Barium,	68 $\frac{1}{2}$	36. Norium,	<i>x</i>
5. Bismuth,	210	37. Osmium,	99 $\frac{1}{2}$
6. Boron,	11	38. Oxygen,	8
7. Bromine,	80	39. Palladium,	53 $\frac{1}{4}$
8. Cadmium,	56	40. Phosphorus,	31
9. Cæsium,	123	41. Platinum,	98 $\frac{1}{2}$
10. Calcium,	20	42. Potassium,	39
11. Carbon,	6	43. Rhodium,	52
12. Cerium,	47	44. Rubidium,	85
13. Chlorine,	35 $\frac{1}{2}$	45. Ruthenium,	52
14. Chromium,	26 $\frac{1}{4}$	46. Selenium,	39 $\frac{3}{4}$
15. Cobalt,	29 $\frac{1}{2}$	47. Silicon,	21
16. Copper,	31 $\frac{3}{4}$	48. Silver,	108
17. Didymium,	48	49. Sodium,	23
18. Erbium,	<i>x</i>	50. Strontium,	43 $\frac{3}{4}$
19. Fluorine,	19	51. Sulphur,	16
20. Glueinum,	7	52. Tantalum,	68 $\frac{3}{4}$
21. Gold,	196 $\frac{1}{2}$	53. Tellurium,	64 $\frac{1}{2}$
22. Hydrogen,	1	54. Terbium,	<i>x</i>
23. Iodine,	127	55. Thallium,	204
24. Iridium,	98 $\frac{1}{2}$	56. Thorium,	39 $\frac{1}{2}$
25. Iron,	28	57. Tin,	59
26. Lanthanum,	47	58. Titanium,	25
27. Lead,	103 $\frac{1}{2}$	59. Tungsten,	92
28. Lithium,	7	60. Vanadium,	68 $\frac{1}{2}$
29. Magnesium,	12	61. Uranium,	60
30. Manganese,	27 $\frac{1}{2}$	62. Yttrium,	<i>x</i>
31. Mercury,	100	63. Zinc,	32 $\frac{1}{2}$
32. Molybdenum,	48	64. Zirconium,	33 $\frac{1}{2}$

Many of these elements are so rare as to be merely objects of scientific curiosity with chemists, and many others enter into the composition of minerals, that seldom form constituents of rock masses; so that, of the whole number of elements and minerals known, it is not necessary to have a minute knowledge of more than one-fourth.

By far the most important of all the elements, are *oxygen* and *sulphur*, which, owing to their powerful affinities, enter into more mineral combinations than any other elements; after these come *carbon* and *silicon*, and then follow *fluorine*, *chlorine*, *phosphorus*, *arsenic*, and *aluminium*.

Arranging the elements in the order of practical importance, and placing after each the names of the groups of minerals derived from it, we have—

1. Oxygen,	producing the Oxidized Stones.
2. Sulphur,	„ the Sulphurets and Sulphates.
3. Carbon,	„ the Carbonates.
4. Silicon,	„ the Silicates.
5. Fluorine and Chlorine,	„ the Fluorides and Chlorides.
6. Phosphorus,	„ the Phosphates.
7. Arsenic,	„ the Arseniurets and Arseniates.
8. Aluminium,	„ Compounds of Alumina.

The first subdivision of minerals contains the Oxygen Compounds, which may be again subdivided as follows:—

Oxygen Compounds.

1. Simple Oxides.
2. Compound Oxides.
3. Silicates.
4. Tantalates, Titanates, Vanadates.
5. Sulphates.
6. Borates.
7. Phosphates.
8. Nitrates.
9. Carbonates.

2. **The Simple Oxides.**—Under the name of Oxides are included both the Simple and Compound Oxides of elementary bodies; and there are several elements that furnish such compounds, viz., *silicon, aluminium, iron, copper, titanium*, &c. The following are the Simple Oxides most frequently met with in nature:—

A. *Quartz Family.*—This is the most abundant of all minerals, and enters freely into combination with many of the elements. It is composed of one atom of silicon, combined with three atoms of oxygen, and therefore contains—

Silicon,	21	46 $\frac{2}{3}$ per cent.
Oxygen,	24	53 $\frac{1}{3}$ „
	<hr/> 45	<hr/> 100

Pure Quartz occurs in crystals of the Hexagonal system (Figs. 27 and 28), and is either colourless and limpid, or variously coloured and more or less opaque, giving rise to the varieties called smoked quartz, rose quartz, &c.

Quartz, or pure Silica, is nearly insoluble in water and common acids, but under favourable circumstances may be taken up by water in quantities sufficiently large to become appreciable after a long lapse of time. Thus, the water of the Geysers in Iceland contain $\frac{1}{18300}$ per cent. of Silica, and sea water contains sometimes $\frac{3}{100000}$ per cent.

Quartz forms an important constituent of many rocks, such as Quartzite, Sandstone, Granite, &c., and the following are the principal varieties of this mineral:—

- (a.) *Amethyst.*—A violet-coloured quartz.
- (b.) *Chalcedony.*—An opaque variety, containing a small quantity of water in combination with the Silica, and coloured of various shades, from white to red; contains the stones called Carnelian.
- (c.) *Agate.*—Consists of alternate layers of pure Quartz and Chalcedony, variously coloured, and called, from the forms of the

layers exposed in section, fortification agate, ring agate, &c. It occurs chiefly, deposited from solution in water, in cavities (geodes) of volcanic rocks and in mineral veins.

- (d.) *Jasper*.—Opaque quartz, coloured yellow, red, &c., by peroxide of iron intimately associated with it. It is found in the bog iron ore of Germany, in pebbles rolled by water in the sand of the Nile and Desert of Egypt, and in small subordinate beds elsewhere.
- (e.) *Flint*.—Semi-opaque quartz, deposited in limestone rocks in the form of nodules, probably by the help of organic agency; the dark-coloured flints are found in white chalk and white Jura limestone, and owe their colour to carbon; the light-coloured flints are called *chert*, and are frequently found to contain fossil corals, wood, &c.; and the pure black flints are called *Lydian stone*, still used as a touchstone for testing the purity of gold.
- (f.) *Opal*.—Opal is quartz, containing from 4 to 10 per cent. of water in combination. The *precious* or *fire* opal exhibits a play of colours of bright hyacinth red and yellow, and is found in cavities of the trachyte rocks of Hungary; the limpid colourless variety, called *Hyalite*, is found in Mexico and in the Mourne Mountains in basalt and granite; and the brown opaque variety, called *Menilite*, forms knobs and layers in the adhesive slate of Menil Montant, near Paris.

B. *Corundum*.—This mineral is of rare occurrence, but is very interesting, both on account of its composition and the extreme beauty of some of its varieties. It is, like quartz, a simple oxide, consisting of two atoms of aluminium and three atoms of oxygen. Hence its composition is

Aluminium,	27.5	53.4 per cent.
Oxygen,	24.0	46.6 „
	<hr/>	<hr/>
	51.5	100.0
	<hr/>	<hr/>

Corundum is sold as *Emery*, and occurs massive, in metamorphic rocks, in Naxos and Saxony; the precious varieties are transparent, and are found in alluvial beds in Ceylon, China, and Siam. When blue, it is called *Sapphire*, and when red, it is called *Ruby*. The transparent green variety is comparatively little known, and is found in Siam. Corundum crystallizes in the Hexagonal system, and exhibits a great variety of secondary dodecahedrons.

C. *Oxides of Iron*.—There are two important oxides of iron, used frequently as ores, and named the *Red* and *Brown Hæmatite*.

(a.) *Red Hæmatite*.—Occurs in crystals, as specular iron ore and micaceous iron ore in the Rhombohedric or Hexagonal system; when massive, it is of a deep red colour, its powder being named rouge. It is an oxide of iron, similar to the oxide of aluminium known as Corundum, and has the following composition:—

Two atoms of Iron,	56	70 per cent.
Three atoms of Oxygen,	24	30 „
	<hr/>	<hr/>
	80	100
	<hr/>	<hr/>

(b.) *Brown Hæmatite* is a hydrated variety of the former, and contains somewhat variable proportions of water, ranging from 10 to 20 per cent. It bears the same relation to Red Hæmatite that Opal does to Quartz. Like most minerals formed by deposition from water, it occurs frequently in the form of incrustations and stalactites, attached to other rocks.

D. *Oxides of Manganese*.—There are many oxides of Manganese, used as ores of this metal for the production of chlorine gas for manufacturing purposes. The most important and valu-

able of these ores is the mineral called *Pyrolusite*, which has the following composition:—

One atom of Manganese, . . .	27.5 . . .	63.2 per cent.
Two atoms of Oxygen, . . .	16.0 . . .	36.8 „
	<hr/>	<hr/>
	43.5	100.0
	<hr/>	<hr/>

The other oxides of Manganese are named *Hausmannite*, *Braunite*, *Manganite*, and *Psilomelane*; they are all of less value, and most of them of much rarer occurrence, than *Pyrolusite*.

E. *Oxides of Copper*.—There are two oxides of Copper, known to miners as *Red* and *Black* Copper ore.

(a.) *Red Copper Ore*.—Occurs in Octahedrons and Rhombic Dodecahedrons of the Figs. 5 and 11, Monometric system, and has the composition—

Two atoms of Copper, . . .	63.5 . . .	88.8 per cent.
One atom of Oxygen, . . .	8.0 . . .	11.2 „
	<hr/>	<hr/>
	71.5	100.0
	<hr/>	<hr/>

(b.) *Black Copper Ore*.—This mineral is generally found massive, but has been occasionally met with, crystallized, in cubes. It contains only one atom of Copper.

One atom of Copper, . . .	31.75 . . .	79.8 per cent.
One atom of Oxygen, . . .	8.00 . . .	20.2 „
	<hr/>	<hr/>
	39.75	100.0
	<hr/>	<hr/>

The oxides of Copper are usually met with in the shallow parts of metallic lodes, and are produced by the oxidation of the Sulphurets of Copper, caused by the contact of water and atmospheric air with the sulphurets in the upper parts of the lodes.

F. *Tinstone*.—This remarkable and valuable ore is the only

known source of metallic Tin. It is an oxide of the metal, having the following composition :—

One atom of Tin,	59	. . . .	$78\frac{2}{3}$	per cent.
Two atoms of Oxygen, . .	16	. . . .	$21\frac{1}{3}$	„
	<hr/>		<hr/>	
	75		100.0	
	<hr/>		<hr/>	

Tinstone occurs in crystals of the Dimetric system (Fig. 18), and has been found in Cornwall from the most remote antiquity; it is also found in small quantities in Saxony, Austria, and Finland; and in very large quantities in the Malaccas, and in Banca, in the East Indian Isles. Herodotus, 450 B. C., alludes to Cornwall, under the name *Cassiterides*, and it is believed that the Phœnicians traded in Tin between Tyre and Tarshish, in Spain, from the earliest ages. There is, also, good reason for supposing that the tinstones of Cornwall, having been landed in Gaul, were afterwards carried on horseback across that country, by a thirty days' journey, for shipment to the East, on the shores of the Mediterranean.

The present annual production of Tin is as follows :—

Cornwall,	140,000 cwt.
Banca and Malacca,	100,000 „
Saxony,	3,500 „
Austria,	380 „
Sweden and Finland,	750 „
	<hr/>
Total,	244,630 cwt.
	<hr/>

G. *Oxide of Titanium*.—Titanium occurs in nature combined with oxygen in the following proportions :—

One atom of Titanium,	25	. . . .	61	per cent.
Two atoms of Oxygen,	16	. . . .	39	„
	<hr/>		<hr/>	
	41		100.0	
	<hr/>		<hr/>	

Titanic acid, or oxide of Titanium, is found as three distinct minerals, which have all the same composition—

- (a.) *Rutile* — Dimetric, prismatic forms.
- (b.) *Anatase*—Dimetric, octahedric forms.
- (c.) *Brookite*—Trimetric.

It forms a remarkable example of a mineral occurring in two distinct crystalline systems, and yet having the same chemical composition. This phenomenon is called *Dimorphism*, and is illustrated also by the cases of *Sulphur* and *Calc Spar*.

Sulphur occurs in the Trimetric and Monoclinic systems.

Calc Spar occurs in the Rhombohedric and Trimetric systems.

3. The Compound Oxides.—Under the name of Compound Oxides are included all the minerals formed by the combination of one or more oxides, which are not of sufficient importance to form classes by themselves. Other groups of minerals, such as Silicates, Sulphates, Borates, Phosphates, Nitrates, and Carbonates, are as truly compound oxides as those included in the present group; but they are so important as to require separate mention in our classification; and in this instance, as in many others in mineralogy, scientific precision is sacrificed to convenience of description.

A. Spinnelle.—This mineral, when pure, has the following composition:—

One atom of Alumina,	. . .	51.5	. . .	72 per cent.
One atom of Magnesia,	. . .	20.0	. . .	28 „
		<hr/>		<hr/>
		71.0		100
		<hr/>		<hr/>

The pure Spinnelle of Ceylon is reddish pink, and occurs in the Monometric system in octahedrons; its magnesia is often more or less replaced by the oxides of iron, zinc, and manganese, which alter the colour of the mineral from pink to brown and black, without changing its form, which is always the octahedron of Euclid (Fig. 5). This change of composition, within certain

limits, while the crystallographical form remains the same, is called *Isomorphism*, and is the converse of the phenomenon already described as *Dimorphism*, which implies change of crystalline form with identity of composition.

B. *Magnetic Iron Ore*.—This mineral occurs in octahedrons of the Monometric system, and forms, when massive, the celebrated “lodestone” of the ancients. Its composition is as follows :—

One atom of Peroxide of Iron, . 80 . . .	68.4 per cent.
One atom of Protoxide of Iron, . 36 . . .	31.6 „
<hr/>	<hr/>
116	100.0
<hr/>	<hr/>

It is one of the most valuable of the ores of iron, and is found in large quantities in the metamorphic rocks of Sweden and Norway. It is closely allied to the compound oxides called Chrome Iron Ore, and Titaniferous Iron Ore, which are of frequent occurrence in similar deposits.

4. **The Silicates**.—As Silica is the most abundant of all the oxides, so we find the Silicates to be the most important of all the compound oxides, and to enter more largely than any other minerals into the composition of rock masses. The Silicates may be divided, for convenience of description, into the following families :—

Silicates.

1. Felspar Family.
2. Hornblende Family.
3. Mica Family.
4. Talc Family.
5. Zeolite Family.
6. Andalusite Family.
7. Garnet Family.

5. **The Felspar Family**.—The Felspars form the chief constituent of almost all the rocks produced by igneous agency, or me-

tamorphic rocks produced by the joint action of water and heat. Some of the feldspars belong exclusively to the oldest granites, and others are equally characteristic of the most modern volcanic rocks, so that they admit of a geological, as well as of a chemical or mineralogical classification.

A. *Orthoclase or Potash Feldspar*.—This mineral occurs in crystals of the Monoclinic system, often combined in twins or *maeles*. It is found chiefly in the granite rocks, of which it is a characteristic constituent. Orthoclase, when perfectly pure, consists of a double or compound silicate of alumina and potash, and has the following composition :—

Four atoms of Silica, . . .	180.0 . . .	64.8 per cent.
One atom of Alumina, . . .	51.5 . . .	18.4 „
One atom of Potash, . . .	47.0 . . .	16.8 „
	<hr/> 278.5	<hr/> 100.0

The foregoing may be regarded as the typical constitution of Orthoclase, but it is found in practice that it is never perfectly pure, as some of the potash is always replaced by soda, lime, and magnesia, in small quantities, without any alteration in the crystalline form of the mineral. The following is the mean of seven analyses of different specimens collected from the granite of Leinster, which is seventy miles in length, and forms the largest mass of granite in the British Islands.

Orthoclase Feldspar (Leinster).

Silica,	64.59	65.05 per cent.
Alumina,	18.31	18.44 „
Potash,	12.23	12.32 „
Soda,	2.75	2.77 „
Magnesia,	0.58	0.58 „
Lime,	0.25	0.25 „
Water,	0.58	0.59 „
	<hr/> 99.26	<hr/> 100.0

The silica and alumina, in this analysis, are the same as in the typical Orthoclase, but the potash is partially replaced by soda, &c.

The following are the principal varieties of this important mineral:—

- (a) *Adularia* or *Moonstone*.—A colourless, semitransparent variety.
- (b.) *Sanidine*, or *Glassy Felspar*.—A vitreous, creviced, transparent Orthoclase, never found in granitic rocks, but characteristic of the volcanic rocks called Trachyte.
- (c.) *Sunstone*.—This is a name given to semitransparent felspars (sometimes *oligoclase*), which in crystallising have entangled minute scales of oxide of iron, which are scattered through the mineral, and give a reflection of light, much admired by jewellers.
- (d.) *Amazon Stone*.—This is a green felspar, found in Siberia and Greenland; that of Siberia owes its green colour to copper, and that of Greenland, to iron protoxide.

B. *Albite*, or *Soda Felspar*.—This felspar has the same composition as Orthoclase, with the exception that soda is substituted for potash. When perfectly pure, its composition is—

Four atoms of Silica, . . .	180.0	68.7 per cent.
One atom of Alumina, . . .	51.5	19.5 „
One atom of Soda, . . .	31.0	11.8 „
	<hr/>	<hr/>
	262.5	100.0
	<hr/>	<hr/>

Albite is a much rarer mineral than Orthoclase, but is found associated with it as a constituent of the granites of the Mourne Mountains; its soda is partly replaced by potash, lime, and magnesia, without changing its crystallographic form, which is *triclinic* and essentially distinct from that of Orthoclase, which is monoclinic; this is one of the arguments used by mineralogists to

prove that potash and soda are not isomorphous in their combinations. The following is the composition of the Albite found in the granite of the Mourne Mountains :—

Albite Felspar (Mourne).

Silica,	68.97 per cent.
Alumina,	19.23 „
Soda,	8.71 „
Potash,	1.56 „
Lime,	1.21 „
Magnesia,	0.24 „
Loss,	0.08 „
	<hr/>
	100.00
	<hr/>

It is evident, on comparing the foregoing analysis with the theoretical composition of Albite, regarded as a double silicate of alumina and soda, that its silica and alumina are the same as those of the perfect mineral, while its soda is partly replaced by potash, lime, and magnesia.

C. *Oligoclase, or Soda and Lime Felspar.*—This felspar, like the two preceding, is often found as a constituent of granite, and occurs in this connexion in Donegal, Scotland, and Sweden. It is triclinic in the form of its crystals; and contains less silica than either orthoclase or albite, for it has only three atoms of silica to one of alumina, and one of soda and lime mixed; when quite pure, its composition is—

Three atoms of Silica, . . .	135.0 . . .	62.50 per cent.
One atom of Alumina, . . .	51.5 . . .	23.84 „
Half atom of Soda, . . .	15.5 . . .	7.18 „
Half atom of Lime, . . .	14.0 . . .	6.48 „
	<hr/>	<hr/>
	216.0	100.00
	<hr/>	<hr/>

The following analysis shows the actual composition of the Oligoclase of Donegal :—

Oligoclase Felspar (Donegal).

Silica,	59.92 . . .	60.56 per cent.
Alumina and Per- oxide of Iron, }	. . . 24.85 . . .	25.12 „
Soda,	6.47 . . .	6.54 „
Lime,	5.30 . . .	5.35 „
Potash,	2.07 . . .	2.09 „
Magnesia,	0.13 . . .	0.13 „
Protoxides of Iron and Manganese, }	. . . 0.21 . . .	0.21 „
	<hr/> 98.95	<hr/> 100.00

Oligoclase is an essential ingredient, associated with Hornblende, in many syenites, and other trap rocks.

D. *Labradorite*.—This is a lime, or lime and soda felspar, consisting essentially of a double silicate of alumina and lime, having the following composition:—

Two atoms of Silica, . . .	90.0 . . .	53.1 per cent.
One atom of Alumina, . . .	51.5 . . .	30.4 „
One atom of Lime, . . .	28.0 . . .	16.5 „
	<hr/> 169.5	<hr/> 100.0

Labradorite is triclinic in its crystallization, and is often found to afford a rich play of iridescent colours, but is sometimes quite white. It is found occasionally in metamorphic beds of gneiss, but does not occur in granite. The following analysis shows the actual composition of the Labradorite found in Loch Seavig, in Skye, as a constituent of the celebrated Syenite of that locality:—

Labradorite Felspar (Skye).

Silica,	53.60 . . .	53.44 per cent.
Alumina,	29.88 . . .	29.80 „
Lime,	11.02 . . .	10.99 „
Soda,	4.92 . . .	4.90 „
Potash,	0.80 . . .	0.80 „
Magnesia,	0.07 . . .	0.07 „
	<hr/> 100.29	<hr/> 100.0

This analysis shows that some of the lime of the theoretical mineral is replaced in nature by soda, without any alteration of form or other physical qualities. It would almost appear, from a comparison of many Labradorites, especially those found in the metamorphic rocks of Eggersund, in Norway, as if the soda replaced the lime in composition, in the proportion of one atom to three. This supposition gives us a theoretical formula for Labradorite, viz. :—

Two atoms of Silica,	90.00	. . .	52.9 per cent.
One atom of Alumina,	51.50	. . .	30.2 „
Three-fourths of an atom of Lime,	21.00	. . .	12.3 „
One-fourth of an atom of Soda,	7.75	. . .	4.6 „
	<hr/>		<hr/>
	170.25		100.0
	<hr/>		<hr/>

The agreement of this theoretical formula with the actual analysis of Labradorite is very close.

E. *Anorthite*.—This is a lime felspar, and is found in many trap rocks, but is unknown in granites. It is a double silicate of lime and alumina, having the following theoretical composition :—

Three atoms of Silica,	135	. . .	45.9 per cent.
Two atoms of Alumina,	103	. . .	35.0 „
Two atoms of Lime,	56	. . .	19.1 „
	<hr/>		<hr/>
	294		100.0
	<hr/>		<hr/>

Anorthite is the most basic of all the felspars, and has been frequently found in lavas and meteoric stones. A remarkable trap rock occurs in Carlingford mountain, composed of Anorthite and Augite; the Anorthite has the following composition :—

Anorthite Felspar (Carlingford).

Silica,	45.87
Alumina,	34.73
Lime,	17.10
Magnesia,	1.55
	<hr/>
	99.25
	<hr/>

Here we see that the lime is partially replaced by magnesia. Collecting together into one table the compositions of the five feldspars, we obtain as follows—arranging them according to their richness in Silica:—

	Albite.	Orthoclase.	Oligoclase.	Labradorite.	Anorthite.
	per cent.	per cent.	per cent.	per cent.	per cent.
Silica,	68.7	64.8	62.5	52.9	45.9
Alumina, . . .	19.5	18.4	23.8	30.2	35.0
Potash,	—	16.8	—	—	—
Soda,	11.8	—	7.2	4.6	—
Lime,	—	—	6.5	12.3	19.1

F. Leucite.—This remarkable mineral performs the function of a true felspar in volcanic rocks, and has never been found in any rocks, except the lavas and traps. It occurs in crystals having the form of the Deltoidal Octahedron (Fig. 16), which is often called, after this mineral, the *Leucitohedron*. Its colour is greyish white, its lustre glassy, and it is semitransparent. It has the following composition:—

Eight atoms of Silica, . . .	360.0	. . .	54.9 per cent.
Three atoms of Alumina, . .	154.5	. . .	23.6 „
Three atoms of Potash, . .	141.0	. . .	21.5 „
	<u>655.5</u>		<u>100.0</u>

Leucite abounds in trachyte between Lake Laach and Andernach, on the Rhine, but the finest crystals are found in the lavas of Vesuvius, and in the old lavas near Rome. It is remarkable, historically, as the mineral in which Klaproth first discovered that potash (so called *vegetable* alkali) was a constituent of the mineral kingdom. The analysis of Klaproth is so interesting and accurate, that I add it here, for the purpose of comparison with the theoretically perfect type given above.

Leucite Felspar (Vesuvius).

Silica,	53.75
Alumina,	24.63
Potash,	21.35
	<hr/>
	99.73
	<hr/>

G. *Nepheline*, or *Elæolite*.—This mineral, like *Leucite*, may be regarded as a volcanic, or semivolcanic felspar. It occurs in the hexagonal system of crystals, with a basic cleavage showing hexagons imbedded in the rock in which it occurs. The variety known as *Nepheline* is colourless, and is found in volcanic rocks only, in which it performs the functions of a true felspar. The variety known as *Elæolite* has various shades of colour—green, brown, red, and is massive, with a glassy lustre on its surfaces of cleavage, and an eminently resinous lustre on its surfaces of cross fracture, from which it derives its name. *Elæolite* forms a connecting link between the volcanic rocks and the older plutonic rocks, by entering largely into the composition of *Zircon Syenite*, in Norway and in the Ural Mountains. It has the following composition:—

Three atoms of Silica,	135	. . . . .	45.0	per cent.
Two atoms of Alumina,	103	. . . . .	34.3	„
Two atoms of Soda,	62	. . . . .	20.7	„
	<hr/>		<hr/>	
	300		100.0	
	<hr/>		<hr/>	

I add here, for the purpose of comparison, Arfvedson's analysis of pure *Nepheline* from Monte Somma.

Nepheline Felspar (Monte Somma).

Silica,	44.11
Alumina,	33.73
Soda,	20.46
Water,	0.62
	<hr/>
	98.92
	<hr/>

The soda in Nepheline is often partially replaced by potash, just as in Leucite, the potash is sometimes partly replaced by soda. *Leucite* and *Nepheline* are, in fact, the potash and soda felspars of the volcanic rocks, just as *Orthoclase* and *Albite* are the potash and soda felspars of the plutonic rocks; and this analogy is carried out even in the forms of the crystals, for Nepheline and Leucite are Hexagonal and Monometric respectively, while Albite and Orthoclase are, respectively, triclinic and monoclinic; in each case the most complex form of crystal belonging to the mineral in which soda largely occurs.

6. The Hornblende Family.—This important group of minerals is chiefly interesting in consequence of its entering extensively into the composition of rocks of igneous origin; most of these rocks are formed principally of a felspar and of a hornblende, which seem to be the opposite poles round which the different elements grouped themselves on cooling. The Felspar family is remarkable for containing large quantities of alkalis and lime, while the Hornblende family, on the other hand, appropriates to itself quantities of iron and magnesia.

A. Hornblende.—This well-known mineral occurs in crystals of the Monoclinic system, having cleavage planes that form angles of $124\frac{1}{2}^{\circ}$ and $55\frac{1}{2}^{\circ}$; being nearly those of a regular hexagon and equilateral triangle. It is generally of various shades of green, up to black, according to the quantity of iron it contains. Hornblende may be regarded as a compound of three atoms of silica with four atoms of magnesia, lime, or protoxide of iron, and its composition varies with the preponderance of one or other of these bases.

The following are the chief varieties of hornblende :—

- (a.) *Tremolite*.—This is a magnesia and lime hornblende, quite white, and not found in the igneous rocks; it is usually found in metamorphic limestone, especially in the metamor-

phic dolomite of the Val Tremola, St. Gothard, from which locality it derives its name; semi-transparent.

- (b.) *Actinolite*.—This is a hornblende, of a beautiful grass green, due to the presence of 6–8 per cent. of protoxide of iron; it is found generally in metamorphic talcose slates, and never in igneous rocks; semi-transparent.
- (c.) *Hornblende proper*.—Colour dark green or black, opaque; contains large quantities of iron and of alumina, which appears partially to discharge the duty of silica. It is one of the most important of rock minerals, and constantly appears as a constituent of the igneous rocks.

B. Augite.—This mineral is closely allied to hornblende, but differs from it in crystalline form, and slightly in chemical composition. It occurs in the Monoclinic system, with cleavage planes making nearly a right angle with each other. Its composition consists of two atoms of silica combined with three atoms of magnesia, lime, or iron protoxide; and, like hornblende, it varies greatly with the change of base. The chief varieties of augite are—

- (a.) *Diopside, or white Augite*.—This variety corresponds with *Tremolite*, and contains no iron; found in metamorphic rocks.
- (b.) *Sahlite*.—Contains some iron, which gives it a pale green colour; corresponds to *actinolite*.
- (c.) *Augite proper, or Pyroxene*.—Green to black in colour; forms an essential constituent of the more modern igneous rocks, free from quartz; like *Hornblende proper*, this mineral contains alumina that seems to replace some of the silica, and discharge its functions.

The difference between hornblende and augite is only slight, and appears, in the case of the igneous rocks, to have been occasioned by slight differences in physical conditions in the cooling

of the rock, and slight chemical differences in the composition of the rock paste, such as the presence or absence of free silica. Hornblende, as a rule, characterizes the older igneous rocks, and Augite, the more modern.

I add here, for the sake of comparison, the analyses of two Augites, one from Carlingford, associated with Anorthite felspar; and the other from Loch Scavig, Skye, associated with Labradorite felspar.

Augite (Carlingford and Scavig).

	<i>Carlingford.</i>	<i>Scavig.</i>
Silica,	50.72	50.80
Alumina,	9.36	3.00 ^a
Protoxide of Iron, . .	18.61	9.61
Lime,	16.96	19.35
Magnesia,	2.40	15.06
Soda,	—	0.44
Potash,	—	0.22
Protoxide of Manganese,	—	1.08
	<hr/> 98.05	<hr/> 99.56

The Augite of the Anorthite Syenite abounds in iron; that of the Labradorite Syenite, in magnesia.

7. The Mica Family.—This group of minerals is easily recognized by their remarkable foliation, which occurs to a degree not known in any other family of minerals. They are found in the igneous rocks, and in metamorphic rocks, and are eminently characteristic of the rock masses in which they are found. They are divisible into two groups, the first of which is characterized by the large amount of alumina and potash (or other alkalies) found in it, and the second by the large quantity of iron and magnesia that form essential constituents of the mineral. These two groups are also distinguishable by their optical properties, being binaxial and uniaxial respectively; and are also, in general, distinguishable by their colours, as the second group has a dark colour, due to the presence of iron.

A. *White, or Binaxial Mica*.—This mineral is found in crystals of the *Trimetric* system, with an eminently basal cleavage, and with angles in its primary rhomb not differing much from 120° , or the angle of the regular hexagon. White Mica consists essentially of one atom of silicate of potash, combined with m atoms of silicate of alumina— m is generally 4, 3, or 2.

(a.) *Muscovite*.—This is the name given to white mica, when $m = 4$, or $m = 3$; its composition in these two cases is—

$m = 4$.

Five atoms of Silica, . . .	225	. . . .	47.1	per cent.
Four atoms of Alumina, . .	206	. . . .	43.1	„
One atom of Potash, . . .	47	. . . .	9.8	„
	<hr/>		<hr/>	
	478		100.0	
	<hr/>		<hr/>	

$m = 3$.

Four atoms of Silica, . . .	180.0	. . . .	47.2	per cent.
Three atoms of Alumina, .	154.5	. . . .	40.5	„
One atom of Potash, . . .	47.0	. . . .	12.3	„
	<hr/>		<hr/>	
	381.5		100.0	
	<hr/>		<hr/>	

This form of white mica has not been yet found among British granites, but is said to occur elsewhere.

(b.) *Margarodite*.—This is the white mica in which there is one atom of water, and

$m = 2$.

Three atoms of Silica, . . .	135	. . . .	45.9	per cent.
Two atoms of Alumina, . .	103	. . . .	35.0	„
One atom of Potash, . . .	47	. . . .	16.0	„
One atom of Water, . . .	9	. . . .	3.1	„
	<hr/>		<hr/>	
	294		100.0	
	<hr/>		<hr/>	

Margarodite is the white mica of the Irish granites, and occurs abundantly in Leinster and Donegal. Its average composition in these two districts is as follows:—

Margarodite Mica (Donegal).

Silica,	45.02	. . . . .	45.02
Alumina,	35.64	}	37.88
Iron Peroxide,	2.24		
Potash,	11.44	}	13.77
Soda,	0.43		
Lime,	0.48		
Magnesia,	0.71		
Iron Protoxide,	0.71		
Water,	3.00	. . . . .	3.00
			<hr/> 99.67

Margarodite Mica (Leinster).

Silica,	44.58	. . . . .	44.58
Alumina,	32.13	}	36.62
Iron Peroxide,	4.49		
Potash,	10.67	}	13.23
Soda,	0.95		
Lime,	0.78		
Magnesia,	0.76		
Iron Protoxide,	0.07		
Water,	5.34	. . . . .	5.34
			<hr/> 99.77

In these analyses we see, as frequently happens in other cases, that part of the alumina is replaced by iron peroxide, and part of the potash by soda and the earths.

(c.) *Lepidolite*.—This is a binaxial mica, of a pink or reddish colour, in which potash is largely replaced by the rare alkali, lithia. It is found only in beds of granite and gneiss, near tin or other metallic lodes, and does not form a constituent of rock masses, on a large scale.

• *B. Black, or Uniaxial Mica*.—The white micas just described are remarkable for containing large quantities of alumina and potash, or other alkalies, but contain very little iron or mag-

nesia; the black or uniaxial micas, now to be noticed, contain, on the contrary, large quantities, either of magnesia, or of iron, or of both. They possess the characteristic appearance of mica, and are generally of a dark colour—brown, green, or jet black; they are found in crystals, quite flat and sectile, generally hexagons, and are considered to belong to the hexagonal system. There are two kinds of Uniaxial Mica, *Biotite* and *Lepidomelane*; in the first of which there is a large quantity of magnesia, and in the second, a large quantity of iron.

- (a.) *Biotite, or Magnesian Mica*.—Colour dark green, brown, or black; crystalline system hexagonal. Has usually the following composition:—

Biotite Mica (Lake Baikal).

Silica,	42.01
Alumina,	16.05
Iron Peroxide,	4.93
Magnesia,	25.97
Potash,	7.55
Water?	2.28
	<hr/>
	98.79

- (b.) *Lepidomelane, or Iron Mica*.—Colour jet black, due to the presence of manganese; from this circumstance, this mica is called by Breithaupt, the *Raven Mica*; occurs in the hexagonal system of crystals. It was formerly considered a rare mineral, but is now well known to be the common kind of black mica, that usually occurs in granite rocks. It is found in the granites of Leinster, Donegal, and Sweden, with the following compositions:—

Lepidomelane Mica (Leinster, Donegal, Sweden).

	<i>Leinster.</i>	<i>Donegal.</i>	<i>Sweden.</i>
Silica,	35.55 . . .	36.20 . . .	32.60
Alumina,	17.08 . . .	15.95 . . .	15.56
Iron Peroxide,	23.70 . . .	27.19 . . .	27.94

	<i>Leinster.</i>	<i>Donegal.</i>	<i>Sweden.</i>
Potash,	9.45 . . .	8.65 . . .	4.30
Soda,	0.35 . . .	0.16 . . .	0.82
Magnesia,	3.07 . . .	5.00 . . .	4.79
Lime,	0.61 . . .	0.50 . . .	1.15
Protoxide of Iron,	3.55 . . .	0.64 . . .	7.45
Protoxide of Manganese, .	1.95 . . .	1.50 . . .	0.80
Water,	4.30 . . .	3.90 . . .	6.80
	<u>99.61</u>	<u>99.69</u>	<u>102.21</u>

8. **The Talc Family.**—This constitutes a very important group of minerals, which agree in containing large quantities of magnesia or iron, and in showing a strong tendency to assume hydrated forms, in consequence of the metamorphic action of water, doubtless aided by a high temperature. The family contains three principal members; viz. :—

- A. The Talcs.
- B. The Serpentine.
- C. The Chlorites.

A. *The Talcs.*—Talc is a mineral rarely crystallized, occurring in foliated or scaly masses; it resembles mica in its cleavage, and has always a greasy* feel; its laminæ are flexible, but not elastic, like those of mica; and it has a mother of pearl lustre. When pure, it has the following composition :—

Five atoms of Silica, . . .	225 . . .	63.6 per cent.
Six atoms of Magnesia, . . .	120 . . .	33.9 „
One atom of Water, . . .	9 . . .	2.5 „
	<u>354</u>	<u>100.0</u>

(a.) *Talc* forms an important constituent of the metamorphic granites and gneiss rocks of the Alps, and is found to

* The peculiar feel of a mineral, which is called *greasy*, seems to me to be confined to the highly magnesian silicates, and to the hydrated aluminous silicates.

enter into the composition of many of the beds that flank the main chain of those mountains, although it is excluded from the granites proper, that form the true axis of the chain. The granitoid metamorphic gneiss, in which talc is found, is called *Protogene*. The following analysis of talc from the protogene rocks of Handeck, near the Grimsel, is added for the purpose of comparison with the typical talc.

Talc (Grimsel).

Silica,	61.20
Alumina,	0.60
Peroxide of Iron,	2.38
Magnesia,	30.80
Lime,	0.23
Potash,	0.11
Soda,	0.06
Iron Protoxide,	0.92
Water,	1.20
	<hr/>
	97.50

- (b.) *Meerschaum* is a form of hydrated talc, having a definite composition.
- (c.) *Steatite*, or German Soapstone, is also an hydrated talc.
- (d.) *Saponite*, or English Soapstone, is a mineral often confounded with *Steatite*, but differs essentially from it in composition; it is a double hydrated silicate of alumina and magnesia, found at the Lizard, in Cornwall; and is there formed by granite veins penetrating *Serpentine*; it is probable that the granite supplies the alumina, and the *Serpentine* the magnesia requisite to form this interesting mineral.

B. *The Serpentes*.—*Serpentine* is never found in crystals, but occurs always massive, or fibrous; in the latter state it is called *Serpentine asbestos*. It is a hydrated silicate of magnesia, having the following theoretical composition :—

Four atoms of Silica, . . .	180 . . .	43.5 per cent.
Nine atoms of Magnesia, . . .	180 . . .	43.5 „
Six atoms of Water, . . .	54 . . .	13.0 „
	<hr/> 414	<hr/> 100.0

Serpentine seems to be, in all cases, the result of metamorphic action upon limestones containing magnesia. There is no rock mass so variable in colour and appearance as Serpentine. Its varieties are—

- (a.) *Precious Serpentine*.—Bright coloured and translucent, used in the manufacture of cheap jewellery.
- (b.) *Verd Antique*.—Green Serpentine, mixed with crystalline limestone, a metamorphic limestone. Found in Connemara and Donegal.
- (c.) *Serpentine Porphyry*.—Formed of a reddish paste containing green crystals (Chrysolite?) imbedded in it; occurs at the Lizard, in Cornwall, and is highly valued as an ornamental marble.
- (d.) *Magnetic Serpentine*.—Some varieties of Serpentine contain large quantities of magnetic oxide of iron, and chrome iron; so much so as to affect the magnet sensibly. This rock is found abundantly on the Italian slope of the Alps.

C. *The Chlorites*.—Chlorite is a mineral resembling mica in its mode of crystallization, and has been sometimes confounded with it. It occurs in the hexagonal system, and is to be regarded as essentially an hydrated double silicate of alumina and magnesia—both elements being more or less replaced, occasionally, by peroxide and protoxide of iron, respectively. It is always of a green colour, and has a mother of pearl lustre.

Chlorite has the following theoretical composition :—

Two atoms of Silica, . . .	90.0 . . .	33.6 per cent.
One atom of Alumina, . . .	51.5 . . .	19.2 „
Five atoms of Magnesia, . . .	100.0 . . .	37.2 „
Three atoms of Water, . . .	27.0 . . .	10.0 „
	<hr/> 268.5	<hr/> 100.0

The Talc, Serpentine, and Chlorites, minerals containing large quantities of magnesia, and frequently highly hydrated, are chiefly characteristic of the older metamorphic rocks, serpentine limestones, chlorite schists, protogene gneiss, &c., and in these rocks they seem to perform a function analogous to that of the Zeolites in the volcanic rocks. The Zeolites, like the Talc, are hydrated minerals, but they are remarkable for containing little, if any, magnesia. They occur almost exclusively in volcanic rocks—so much so, that the finding of them in the granitic rocks is always considered a rare phenomenon, and one worthy of record. The talc family, on the other hand, is almost equally restricted to the plutonic and ancient metamorphic rocks.

9. The Zeolite Family.—The Zeolites form a well-marked family of minerals, almost altogether confined, as to their mode of occurrence, to the volcanic rocks. They are all hydrated, and contain but little magnesia and iron, and seem to have been principally formed by the action of heated water. They are generally found in cavities of trap and volcanic rocks, and are most simply classified according to the crystalline system in which they occur, which is, in many cases, easily recognized, and saves the trouble of a chemical analysis in order to determine them. The five groups of Zeolites thus formed are as follows:—

1. The Monometric Zeolites.
2. The Dimetric Zeolites.
3. The Hexagonal Zeolites.
4. The Trimetric Zeolites.
5. The Monoclinic Zeolites.

A. Monometric Zeolites.—(a.) *Analcime*.—Usually found, like Leucite, in Trapezohedrons, or Deltoid Octahedrons (Fig. 16); sometimes in the form of the Cubo-Octahedron (Fig. 8), as in the lavas of Etna. *Analcime* is an hydrated double silicate of alumina and soda, having the following theoretical composition:—

Eight atoms of Silica, . . .	360.0	. . .	54.4 per cent.
Three atoms of Alumina, . .	154.5	. . .	23.3 „
Three atoms of Soda, . . .	93.0	. . .	14.2 „
Six atoms of Water, . . .	54.0	. . .	8.1 „
	<hr/>		<hr/>
	661.5		100.0
	<hr/>		<hr/>

This Zeolite is found chiefly in cavities of old lavas, as in Dumbarton, the Giant's Causeway, the Cyclopean Isles; and is occasionally found in older rocks, as in the silver lodes of Kongsberg and the Hartz; and in the Zircon Syenite of Laurvig, in Norway. The observer must learn to avoid confounding *Analcime* with *Leucite*.

B. *Dimetric Zeolites*.—(a.) *Apophyllite*.—This Zeolite occurs always in crystals of the Dimetric system (Figs. 17 and 18). It is, essentially, an hydrated double silicate of lime and potash, containing very little alumina, and in this latter respect it differs from all the other Zeolites. Its theoretical composition is—

Ten atoms of Silica, . . .	450	. . .	52.0 per cent.
Eight atoms of Lime, . .	224	. . .	26.0 „
One atom of Potash, . . .	47	. . .	5.4 „
Sixteen atoms of Water, .	144	. . .	16.6 „
	<hr/>		<hr/>
	865		100.0
	<hr/>		<hr/>

Apophyllite differs from the other Zeolites, not only in not containing alumina, but also by the presence of a small quantity of Fluorine sometimes amounting to one per cent.

This mineral, like *Analcime*, is found chiefly in cavities of trap rocks (geodes), and also, occasionally, in mineral lodes. Some of the finest specimens come from the great trap field of Western India. I add here, for comparison with the typical composition, the analysis of a fine specimen sent to me from Bombay, by Lieut.-Colonel Montgomery.

Apophyllite (Trap Rocks of Bombay).

Silica,	51.60
Alumina,	0.24
Lime,	25.08
Magnesia,	0.08
Potash,	5.04
Soda,	0.63
Water,	16.20
Fluorine,	0.97
	<hr/>
	99.84
	<hr/>

C. Hexagonal Zeolites.—(a.) *Chabazite.*—This mineral occurs both in rhombohedral and hexagonal forms, and when found in the latter form, it is called Gmelinite by some authors. It is an hydrated double silicate of alumina, and of lime and soda, and varies considerably in its composition. It occurs frequently in the cavities of volcanic and trap rocks, and is easily recognized by the rhombohedral or hexagonal form of its crystals. It has been found, also, in syenite and gneiss in Massachusetts and Connecticut, but is of very rare occurrence, except in the volcanic rocks.

Its composition is as follows:—

Eight atoms of Silica, . . .	360.0	. . .	47.2 per cent.
Three atoms of Alumina, . .	154.5	. . .	20.2 „
Two atoms of Lime, . . .	56.0	. . .	7.3 „
One atom of Soda, . . .	31.0	. . .	4.1 „
Eighteen atoms of Water, .	162.0	. . .	21.2 „
	<hr/>		<hr/>
	763.5		100.0
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D. Trimetric Zeolites.—(a.) *Natrolite, or Soda Needlestone.*—This is the most common of all the trimetric or prismatic Zeolites; it occurs in thin long acicular crystals, generally radiating from a centre. It is essentially an hydrated double

silicate of alumina and soda, and has the following composition :—

Two atoms of Silica, . . .	90.0	. . .	47.2	per cent.
One atom of Alumina, . . .	51.5	. . .	27.0	„
One atom of Soda, . . .	31.0	. . .	16.3	„
Two atoms of Water, . . .	18.0	. . .	9.5	„
	<hr/>		<hr/>	
	190.5		100.0	
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This zeolite occurs chiefly in amygdaloid, basalt, dolerite, and clinkstone. It has been found also among the plutonic rocks at Laurvig and Arendal.

(b.) *Scolezite*, or *Lime Needlestone*.—Occurs in prisms, sometimes acicular and radiated, or fibrous. Its composition is analogous to that of *Natrolite*, or *Soda Needlestone*, only that lime takes the place of soda, and the water in combination is somewhat different :—

Two atoms of Silica, . . .	90.0	. . .	45.8	per cent.
One atom of Alumina, . . .	51.5	. . .	26.2	„
One atom of Lime, . . .	28.0	. . .	14.2	„
Three atoms of Water, . . .	27.0	. . .	13.8	„
	<hr/>		<hr/>	
	196.5		100.0	
	<hr/>		<hr/>	

Many *Zeolites* have been described, under various names, which seem to be either mechanical mixtures of *Natrolite* and *Scolezite*, or true varieties intermediate between these minerals. The following seem not to be entitled to a separate rank :—

1. Lehuntite, of Thomson.
2. Poonahlite, of Brooke.
3. Mesole, of Berzelius.
4. Brevicite, of Berzelius.
5. Harringtonite, of Thomson.
6. Antrimolite, of Thomson.
7. Stellite, of Thomson.

The following analysis of a specimen sent to me by Colonel Montgomery, from Bombay, of a mineral not distinguishable from Harringtonite, occurring in large massive nodules, of feathery structure, filling cavities in trap rocks, shows its affinity to *Lime Mesotype*, or *Scolecite*.

Harringtonite (Bombay).

Silica,	45.60
Alumina,	27.30
Lime,	12.12
Magnesia,	trace.
Soda,	2.76
Potash,	0.63
Water,	12.99
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	101.40
	<hr/>

(c.) *Prehnite*.—This zeolite, like natrolite, occurs in fan-shaped masses, formed of radiating prisms; having externally a spheroidal appearance. It is generally of a pale green colour, and is easily recognized. It is an hydrated double silicate of alumina and lime, with enough iron protoxide to give the mineral its characteristic colour. Its composition is as follows:—

Two atoms of Silica,	90.0	. . . . .	43.6	per cent.
One atom of Alumina,	51.5	. . . . .	25.0	„
Two atoms of lime,	56.0	. . . . .	27.1	„
One atom of Water,	9.0	. . . . .	4.3	„
	<hr/>		<hr/>	
	206.5		100.0	
	<hr/>		<hr/>	

This zeolite was first found by Colonel Prehn, at the Cape of Good Hope, and was named after him by Werner; it is occasionally found in the granitic rocks, but its usual habitat is the trap series.

(d.) *Thomsonite*, or *Lime and Soda Needlestone*.—This is one of the zeolitic minerals, to which the general names of *needle-*

stone and *mesotype* were given by the older mineralogists. It differs essentially in its composition from Natrolite; but resembles it in its mode of crystallization, and in the fan-shaped radiated masses in which its crystals are usually found. Its composition, regarding it as a double silicate of alumina, and of lime and soda hydrated, is—

Four atoms of Silica, . . .	180.0	. . .	37.1	per cent.
Three atoms of Alumina, . . .	154.5	. . .	31.9	„
Two atoms of Lime, . . .	56.0	. . .	11.5	„
One atom of Soda, . . .	31.0	. . .	6.4	„
Seven atoms of Water, . . .	63.0	. . .	13.1	„
	<hr/>		<hr/>	
	484.5		100.0	
	<hr/>		<hr/>	

Thomsonite is found with calc spar and zeolitic minerals in cavities in amygdaloid, basalt, dolerite, clinkstone, and old lavas.

(e.) *Harmotome*.—This zeolite is sometimes called cross-stone, because its crystals are usually found placed regularly in pairs (*macles*) intersecting each other symmetrically, so as to form a Maltese cross in section. It is a double hydrated silicate of alumina and barytes, having the following composition :—

Three atoms of Silica, . . .	135.0	. . .	43.8	per cent.
One atom of Alumina, . . .	51.5	. . .	16.8	„
One atom of Barytes, . . .	76.5	. . .	24.8	„
Five atoms of Water, . . .	45.0	. . .	14.6	„
	<hr/>		<hr/>	
	308.0		100.0	
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A variety of *Harmotome*, called *Phillipsite*, is known, in which lime and potash take the place of barytes, but the atomic proportions of the mineral remain as before. The *Harmotomes* are found in amygdaloidal trap and in metallic lodes.

E. *Monoclinic Zeolites*.—(a.) *Stilbite*.—Occurs in broad prisms, frequently clustered into sheaves or bundles; it is also found in massive or fibrous aggregates—sometimes of various

colours, as yellow and red. It is a double hydrated silicate of alumina and lime, having the following composition :—

Four atoms of Silica, . . .	180.0	. . .	57.5	per cent.
One atom of Alumina, . . .	51.5	. . .	16.4	„
One atom of Lime, . . .	28.0	. . .	8.9	„
Six atoms of Water, . . .	54.0	. . .	17.2	„
	<u>313.5</u>		<u>100.0</u>	

The following analyses of very fine specimens from Indian trap rocks may be compared with advantage with the theoretical composition of the mineral :—

Indian Stilbites.

	<i>Nerbudda.</i>	<i>Bombay.</i>
Silica,	56.59	58.20
Alumina,	15.35	15.60
Lime,	5.88	8.07
Magnesia,	0.82	none.
Soda,	1.45	0.49
Potash,	0.89	0.92
Water,	17.48	18.00
	<u>98.46</u>	<u>101.28</u>

Stilbite occurs, like the other zeolites, in amygdaloidal trap rocks and in mineral veins; I have found it, also, in cavities of granite in the Mourne Mountains.

(b.) *Epistilbite, or Heulandite.*—This mineral differs from the zeolite last described, in containing one atom less of water; its composition is, therefore—

Four atoms of Silica, . . .	180.0	. . .	59.1	per cent.
One atom of Alumina, . . .	51.5	. . .	16.9	„
One atom of Lime, . . .	28.0	. . .	9.2	„
Five atoms of Water, . . .	45.0	. . .	14.8	„
	<u>304.5</u>		<u>100.0</u>	

When barytes and strontia replace the lime, a variety of *Epistilbite* occurs, which is called *Brewsterite*. *Heulandite* is the name given to the flat tabular crystals of *Epistilbite*, but the two minerals are essentially the same.

(c.) *Hypostilbite*.—This mineral was first described by Beudant, from the Faroe Isles, and was afterwards found in the trap rocks of the Island of Skye, and has been recently discovered in beautiful stellated radiating crystals in the trap rocks of Bombay, by Colonel Montgomery. It is closely related to *Stilbite* and *Epistilbite*, and has the following composition:—

Ten atoms of Silica, . . .	450.0	. . .	54.0	per cent.
Three atoms of Alumina, . .	154.5	. . .	18.6	„
Three atoms of Lime, . . .	84.0	. . .	10.1	„
Sixteen atoms of Water, . .	144.0	. . .	17.3	„
	<hr/>		<hr/>	
	832.5		100.0	
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(d.) *Laumontite*.—This mineral is very closely allied to the last, if it be not merely a variety of it; and many mineralogists believe both *Hypostilbite* and *Laumontite* to be altered forms of *Stilbite*.

Laumontite has the following composition:—

Eight atoms of Silica, . . .	360.0	. . .	51.0	per cent.
Three atoms of Alumina, . .	154.5	. . .	21.9	„
Three atoms of Lime, . . .	84.0	. . .	11.9	„
Twelve atoms of Water, . .	108.0	. . .	15.2	„
	<hr/>		<hr/>	
	706.5		100.0	
	<hr/>		<hr/>	

10. **The Andalusite Family.**—A number of minerals are usually grouped together under the name of the *Andalusite* section, which are more allied to each other by chemical and physical properties than by geological affinities.

A. *Andalusite*.—This mineral is well known in the older metamorphic rocks; it is trimetric, and occurs most commonly

in rhombic (nearly square) prisms, with flat bases and summits. Its lustre is vitreous, and colour pearl grey to pale red. It is a silicate of alumina, having the following composition:—

Two atoms of Silica, . . .	90.0 . . .	36.8 per cent.
Three atoms of Alumina, . .	154.5 . . .	63.2 „
	<hr/> 244.5	<hr/> 100.0

The following varieties of *Andalusite* are well known:—

- (a.) *Chiastolite*.—This mineral occurs in bunches of crystals, forming “Prince of Wales plumes,” in mica slate, in the neighbourhood of granite, and is distinguished from ordinary *Andalusite* by its extreme softness. It is probably a pseudomorphic variety of this mineral.
- (b.) *Stauroolith, or Cross-stone*.—This is a form of *Andalusite* in which part of the alumina is replaced by peroxide of iron; and it varies in composition according to the proportions of the alumina and iron. It occurs always in twin crystals, intersecting each other in the form of a cross. Like *Andalusite*, it is always found in gneiss or mica slate.
- (c.) *Kyanite*.—This beautiful mineral must be regarded as a dimorphous form of *Andalusite*; it is triclinic, and of a beautiful blue colour, with mother of pearl lustre. It is a pure silicate of alumina, of the same composition as *Andalusite*, and occurs always, like this mineral and *Stauroolith*, in the metamorphic rocks.

B. *Topaz*.—This remarkable mineral is a fluosilicate of alumina, and may be regarded as having the composition of *Andalusite*; viz., two atoms of silica, and three atoms of alumina, one-sixth of the oxygen being replaced by fluorine. The silicate of alumina, called *Andalusite*, may be regarded as a double oxide of silicon and aluminium; and if we imagine a double fluoride of silicon and aluminium in the same proportions, we can convert *Andalusite* into *Topaz*, by combining together five atoms of the

double oxide with one atom of the double fluoride. *Topaz* is trimetric, and occurs in beautiful crystals, with a basal cleavage; it is frequently found, as in the Mourne Mountains, in cavities of granite, and is often associated with *Beryl*, *Schorl*, and *Tinstone*; it is also frequently found, as a constituent part of a metamorphic sandstone, called Topaz rock, in which it is associated with schorl and quartz. *Oriental Topaz* is a variety of *sapphire*.

C. *Beryl*, or *Emerald*.—This beautiful mineral is a double silicate of alumina and glucina, having the following composition:—

Four atoms of Silica,	180.0	66.8 per cent.
One atom of Alumina,	51.5	19.1 „
One atom of Glucina,	38.0	14.1 „
	<hr/> 269.5	<hr/> 100.0

Beryl occurs in hexagonal crystals, and is usually of various shades of blue or green; the most valuable and beautiful crystals known are the blue *Emeralds*, found in a metamorphic dolomite near Santa Fé de Bogota; beryl is frequently found in mica slate and other metamorphic rocks, and is also known to occur as a constituent mineral in granite. Beryls are found in all the granitic districts of Ireland, those of Leinster and Donegal being green, and those of Mourne being blue in colour. The earth, glucina, was discovered in *Beryl*, in 1797, by Vauquelin.

D. *Tourmaline*, or *Schorl*.—This mineral (or minerals) occurs in the hexagonal system, and possesses every variety of transparency. It is of various colours, red, blue, black; and possesses a very variable chemical composition, which is not yet accurately ascertained. It may be regarded, roughly, as a silicate of alumina, consisting of three atoms of silica, and four of alumina—a fourth or fifth of the alumina being replaced by boracic acid—other substances, such as iron, manganese, potash, soda, &c., and also phosphoric acid and fluorine are frequently found in different

kinds of tourmaline, which may justly be regarded as one of the most complex of known minerals.

Tourmaline is a mineral essentially related to the plutonic rocks, and has never been found in the later igneous rocks; in some granites, as in the west of Cornwall, it forms a constituent mineral, and seems to be closely related to the black mica found in the same district. The following varieties are recognized by mineralogists:—

- (a.) *Schorl*.—The jet black variety of tourmaline; is most usually found in the granite rocks.
- (b.) *Rubellite*.—The red transparent variety.
- (c.) *Indicolite*.—The blue tourmalines.
- (d.) *Achoite*.—Transparent, and colourless tourmaline.

E. *Zircon, or Hyacinth*.—This mineral occurs in crystals of the dimetric system, generally columnar and imbedded singly in the matrix; which may be syenite, granite, basaltic lava, or granular limestone. It is associated with *Elaolite* or *Nepheline* in the Zircon Syenites, which form a connecting link between the volcanic and the plutonic rocks. Zircon is prized as a cheap gem, under the name of Jacinth or Hyacinth, and is usually of yellow or red colour. It is a silicate of Zirconia, of simple composition.

One atom of Silica,	45	. . . . .	33.1	per cent.
One atom of Zirconia,	91	. . . . .	66.9	„
	<hr/> 136		<hr/> 100.0	

The earth Zirconia was found by Klaproth, in this mineral, in 1789, and Svanberg has proved that the Norwegian forms of Zircon always contain a portion of the rare earth *Noria*, replacing part of the *Zirconia*.

11. The Garnet Family.—This family of minerals contains a number of species agreeing with each other in having a very basic constitution; they are generally, also, of brilliant lustre, and form the cheaper kinds of gems.

A. *Chrysolite*.—This mineral is also called *Olivene* and *Peridote*. It is trimetric, and frequently found in single columnar crystals; it varies in colour from olive green to brown. It has the following theoretical composition:—

One atom of Silica,	45	. . . . .	43 per cent.
Three atoms of Magnesia,	60	. . . . .	57 „
	<hr/>		
	105		100.0
	<hr/>		<hr/>

In most *Chrysolites*, 10 per cent. of protoxide of iron replaces a portion of the magnesia, and when the iron exceeds this quantity, the mineral is called *Olivene*; when it replaces the magnesia altogether, the mineral is called *Peridote*. The finest crystals of *Chrysolite* come from the granitic rocks of Upper Egypt, and *Peridote* is found in the cavities of granite in the Mourne Mountains; but the chief source of *Olivene* is basalt, and other volcanic rocks, in which this mineral is almost universally present, disseminated in grains through the finer portions of the rock. *Olivene* is found also to occur abundantly in meteoric stones, and its igneous origin is clearly proved, by its frequent occurrence in the cavities of slags, furnished by iron smelting furnaces.

Yttrite, or *Gadolinite*, is a form of *Peridote* in which *Cerium* and *Yttrium* take the place of *Iron*.

B. *Garnet*.—This beautiful mineral is monometric, and usually found in rhombic dodecahedrons (Fig. 11), or in trapezohedrons (Fig. 16); it has every variety of colour, green, red, black; and always a brilliant lustre. The garnets are divided into two groups, the lime garnets and the iron garnets. The lime garnets have the following composition:—

Two atoms of Silica,	90.0	. . . . .	40.0 per cent.
One atom of Alumina,	51.5	. . . . .	22.8 „
Three atoms of Lime,	84.0	. . . . .	37.2 „
	<hr/>		
	225.5		100.0
	<hr/>		<hr/>

The colours of the lime garnets are generally pale greenish, clear red, reddish orange, and cinnamon colour. The following varieties are recognized by mineralogists and jewellers :—

- (a.) *Cinnamon Stone*, or *Essonite*; has a clear cinnamon brown shade.
- (b.) *Grossular*, *Wilnite*, or *Gooseberry garnet*; has a gooseberry green colour.
- (c.) *Succinite*; has an amber colour.
- (d.) *Topazolite*; has the appearance of topaz.
- (e.) *Romanzovite*; is brownish.

The iron garnets have the same composition as the lime garnets, except that protoxide of iron replaces the lime, viz.—

Two atoms of Silica, . . .	90.0 . . .	36.1 per cent.
One atom of Alumina, . . .	51.5 . . .	20.7 ;,
Three atoms of iron Protoxide, . . .	108.0 . . .	43.2 „
	<hr/> 249.5	<hr/> 100.0

The iron garnets exhibit the following varieties :—

- (a'.) *Almandine*—Common garnet; of a dingy red colour.
- (b'.) *Precious garnet*—Of a deep red colour, and transparent, or at least translucent.
- (c'.) *Allochroite*; is fine grained massive iron garnet, of a dark dingy colour.
- (d'.) *Melanite*; is a velvet black garnet, and is much admired.
- (e'.) *Colophonite*; dark reddish black garnet, with a resinous lustre.

Garnet is found in the granitic and metamorphic rocks, especially in mica slate and chlorite slate, and in crystalline metamorphic limestones. It also forms a constituent of several rare rocks, as *Garnet Rock* and *Eklogite*.

Idocrase is a dimorphous form of garnet, occurring in the

Dimetric system, in crystals, columnar or pyramidal, imbedded in the matrix, or adhering to each other; frequently, also, in fibrous compact aggregates. It is found in old lavas, in serpentines and dolomites, and seems to be, generally, the result of metamorphic action.

Orthite is a garnet, in which the oxides of cerium and yttrium take the place of lime.

C. *Epidote*.—This mineral is monoclinic, and generally exhibits a bright green surface, like that of garnet, to which mineral it is closely related. It has the following composition:—

Three atoms of Silica, . . .	135	42 per cent.
Two atoms of Alumina, . . .	103	32 „
Three atoms of Lime, . . .	84	26 „
	<hr/> 322	<hr/> 100

The *Epidotes*, like the *Garnets*, may be divided into Lime Epidotes and Iron Epidotes, together with intermediate varieties, and others depending on the occurrence of manganese in the constitution of the mineral.

- (a.) *Zoisite*; is a grey Epidote, found in granite and crystalline limestone.
- (b.) *Pistacite*; is bright green, and frequently found in the hornblende rocks; it occurs with beds of magnetic oxide of iron, at Arendal, and is sometimes called, for this reason, by the name of *Arendalite*.

D. *Axinite*.—This is a rare mineral, unquestionably related to the Garnet family, but differing from the garnets in containing boracic acid—like *Tourmaline*. In the cliffs, near Botallack mine, *axinite* is found in a rock forming a thin band in the hornblende slate of the neighbourhood, composed of hornblende, quartz, garnet, and schorl. In order to obtain good specimens, the mineralogist is obliged to take off his shoes, and creep down

the face of a dangerous cliff. It may be doubted whether it would be prudent to make the attempt a second time.

E. *Iolite*, or *Cordierite*, is sometimes considered as belonging to the Garnet family, but it seems to be a form of *Nepheline*, and as such is related rather to the Felspar family.

F. *Scapolite*.—This a double silicate of lime and alumina, related to the garnets, and having the composition—

Four atoms of Silica,	. . . 180	49.1 per cent.
Two atoms of Alumina,	. . . 103	28.1 „
Three atoms of Lime,	. . . 84	22.8 „
	<hr/> 367	<hr/> 100.0

Scapolite is found in dimetric prisms in granite and other crystalline rocks, especially in the neighbourhood of metamorphic limestones; and in veins of iron ore, as at Arendal. In Donegal, where many of the granite rocks are gneissose, and associated with bands of limestone, *Scapolite* often occurs in quartzose veins in the granite.

12. **Tantalates, Titanates, and Tungstates, &c. &c.**—The metals, tantalum, titanium, tungsten, vanadium, and niobium, form, by their combination with oxygen, acids which are called tantalic, titanic, tungstic, vanadic, and niobic acids; these acids have the properties of silicic acid, and enter into combination with bases, forming minerals in all respects resembling the silicates. I shall here mention a few of the least rare of these remarkable minerals.

A. *Sphene*, or *Titanite*.—This is a silico-titanate of lime, having the composition—

Two atoms of Silicic Acid,	. . . 90	30.3 per cent.
Three atoms of Titanic acid,	. . . 123	41.4 „
Three atoms of Lime,	. . . 84	28.3 „
	<hr/> 297	<hr/> 100.0

Sphene is monoclinic in its crystallization, and is found in separate crystals in granite and other crystalline rocks; it is generally of a brown colour, and of a resinous lustre, for which reasons, and from the usual size of its crystals, it is known to the quarrymen in Canada by the name of "bed bug." It occurs, scattered through the gneissose granite of Donegal, Norway, and Canada, in such abundance as to give a name to the geological horizon on which it is found.

Titanic acid itself, as we have already mentioned in speaking of the oxides, occurs as a mineral, under the forms of *Brookite*, *Rutile*, and *Anatase*.

B. *Tantalite*, or *Columbite*.—This mineral is trimetric, and has the appearance of tinstone, with which it has sometimes been confounded. It is essentially a combination of Tantalic acid with protoxide of iron, and has the following typical composition:—

One atom of Tantalic or Niobic Acid, . . .	92.75	. . .	72 per cent.
One atom of Iron Protoxide, . . .	36.00	. . .	28 „
	<hr/>		<hr/>
	128.75		100
	<hr/>		<hr/>

Tantalite is usually found in granites, in Finland, and Greenland, and is associated with *albite*, or *oligoclase* felspar, and with other minerals that, like itself, contain Tantalic acid. The proportions in which Tantalic and Niobic acid enter into the composition of *Tantalite* is not known; and, indeed, the properties of Niobium cannot be regarded as yet fully ascertained by chemists.

C. *Wolfram*.—This well-known mineral, like *Tantalite*, resembles Tinstone in colour and lustre; it is trimetric, and occurs generally in lamellar masses, but is sometimes massive granular, the particles being strongly coherent. It is a combination of Tungstic acid with the protoxides of iron and manganese, having the following composition:—

One atom of Tungstic Acid,	116 . .	76.3 per cent.
One atom of Iron and Manganese } Protoxides,	. . 36 . .	23.7 ,,
	<hr/> 152	<hr/> 100.0

Wolfram is frequently found associated with tinstone, which is greatly damaged by its presence, in consequence of the difficulty of separating the tungsten from the tin, by furnace processes, and without having recourse to expensive chemical operations.

Scheelite is a tungstate of lime, having the same composition as *Wolfram*, except that the protoxides of iron and manganese are wholly replaced by lime.

13. The Sulphates.—The sulphates differ in their origin from all the oxygen compounds previously described. Other oxides, as silicates, borates, tantalates, aluminates, &c., seem to have been formed by the direct union of oxygen with silicon, boron, tantalum, &c., and there is no evidence to show that these latter elements existed previously in combination with other bodies; but in the case of the Sulphates, we have reason to believe that they all existed originally in the form of Sulphurets, which have been converted by a metamorphic action, in which oxygen and water were the principal agents, into the minerals known as Sulphates. Among these the following may be mentioned as the most common:—

A. Barytes, or Heavy Spar.—This is a combination of Sulphuric acid with the earth barytes, in the following proportions:—

One atom of Sulphuric Acid,	40.0 . . .	34.3 per cent.
One atom of Barytes,	76.5 . . .	65.7 ,,
	<hr/> 116.5	<hr/> 100.0

Barytes occurs in flat brilliant crystals in the trimetric sys-

tem (Fig. 23), and is of various colours, white, yellow, brown, and red. It is found in metallic lodes, forming a matrix for galena and sulphurets of copper; and it has been found in nodular masses in the clay beds of Monte Paterno, near Bologna, where it is called Bologna spar.

B. Celestine.—This mineral occurs under circumstances similar to those in which Barytes is found; but is frequently fibrous in texture. It consists of sulphuric acid, and the earth Strontites, in the following proportions:—

One atom of Sulphuric Acid,	. . 40.00	. . 43.6 per cent.
One atom of Strontia,	. . . . 51.75	. . 56.4 „
	<hr/> 91.75	<hr/> 100.0

Celestine has been found occasionally in fibrous layers in marly limestone, especially dolomite; but it usually occurs, forming a portion of the earthy matrix of metalliferous veins.

C. Anhydrite.—This is a sulphate of lime, having the composition:—

One atom of Sulphuric Acid,	. . 40	. . 58.8 per cent.
One atom of Lime,	. . . . 28	. . 41.2 „
	<hr/> 68	<hr/> 100.0

Anhydrite, like *Celestine* and *Barytes*, is found to occur in the trimetric system, but crystals of this mineral are rare; it is more usually found massive, in granular aggregates. It is found in metallic lodes, and sometimes bedded in rocks associated with *Gypsum* and *Rock Salt*.

D. Gypsum, or Selenite.—This beautiful mineral is in the monoclinic system. When found in crystals, these are either prismatic or tabular, frequently occurring in twins, and always of great beauty. The mineral is generally called *Selenite* when crystallized in good specimens. When fibrous, granular,

or compact, it is called *Gypsum*. It is flexible in thin plates, and has a mother of pearl lustre on the cleavage planes; a silky lustre on the other faces.

Its composition is as follows :—

One atom of Sulphuric Acid, . . .	40 . .	46.5 per cent.
One atom of Lime,	28 . .	32.6 „
Two atoms of Water,	18 . .	20.9 „
	<hr/> 86	<hr/> 100.0

Gypsum is usually associated in nature with Rock Salt, and there is reason to believe that both minerals are the result of the drying up of ancient sea beds—a process which leaves the salts once held in solution by the water finally deposited in the strata formed at the bottom of the sea.

E. *Alum*.—There are many species of Alum, all of them agreeing in the following composition :—

Four atoms of Sulphuric Acid, . . .	160.0
One atom of Alumina,	51.5
One atom of Protoxide,	<i>x</i>
Twenty-four atoms of Water, . . .	216.0

The undetermined protoxide may be potash, soda, protoxide of iron, &c.; each different protoxide giving origin to a distinct variety of Alum. Thus we may have, potash alum, soda alum, magnesia alum, iron alum, manganese alum, ammonia alum, &c.

Alum is monometric, and usually crystallizes in octahedrons (Fig. 5). Magnificent crystals of this interesting salt may be formed artificially, and grown to any size required, by adding fresh quantities of alum to the solution. Alum is found in nature, formed by the action of sulphuretted hydrogen gas escaping from the craters of volcanoes; but much more frequently as the result of the metamorphic action of air and water upon beds of iron pyrites in shale.

Many other sulphates occur occasionally in nature, but possess more interest for the chemist than for the mineralogist. Among them, the following may be mentioned :—

- (a.) *Glauberite*.—A double sulphate of soda and lime.
- (b.) *Hairsalt, Alunogen*.—An hydrated sulphate of alumina.
- (c.) *Epsom Salt*.—An hydrated sulphate of magnesia.
- (d.) *Glaubersalt*.—An hydrated sulphate of soda.
- (e.) *Alunite*.—A double hydrated sulphate of alumina and potash, differing in the proportions of its constituents from potash Alum.

14. **The Borates.**—Boracic acid, as I have already stated, occurs in several minerals, such as *Tourmaline* and *Axinite*, in which it takes the place, in part, of alumina or silica. There are, also, two well-known minerals, which are pure compounds of the boracic acid with a base; they are both found associated with Rock Salt, and seem to have had their origin, like it, in the drying up of ancient sea beds.

A. *Borax, or Tincal*.—This is a monoclinic mineral, found in broad, short, columnar crystals. It is translucent, with a resinous lustre, and conchoidal fracture. *Borax* has the following composition, showing it to be an hydrated borate of soda :—

Two atoms of Boracic Acid,	. . 70 . .	36.7 per cent.
One atom of Soda,	. . . . 31 . .	16.2 „
Ten atoms of Water,	. . . . 90 . .	47.1 „
	<hr/> 191	<hr/> 100.0

Borax is found in loose crystals and granular aggregations, on the shores of Alpine lakes in Thibet and Nepaul, and in South America, near Potosi; in North America, it has been found at Clear Lake, in California, in crystals several inches long.

B. *Boracite*.—This is a borate of magnesia, having the following composition :—

Four atoms of Boracic Acid,	. . . 140 . . . 70 per cent.
Three atoms of Magnesia,	. . . 60 . . . 30 „
	<hr/>
	200 100
	<hr/>

Boracite occurs in the monometric system, and its crystals are generally combinations of the cube and octahedron—sometimes with faces of the tetrahedron and rhombic dodecahedron added. It is found associated with Gypsum, Anhydrite, and Rock Salt, in several localities in Germany and France.

15. The Phosphates.—Phosphorus is found in meteoric stones in the form of phosphurets, and it may have originally existed in this form in terrestrial minerals; at present, however, it is only known to us in minerals in combination with oxygen, and forming Phosphates. There are four mineral phosphates worthy of notice:—

A. *Apatite*.—This is a phosphate of lime, occurring in the hexagonal system, in short columnar six-sided prisms, generally of a blueish or greenish colour; it is met with frequently in metallic lodes, especially those of tinstone; also as an occasional or even constituent mineral in volcanic and granitic rocks, and abundantly in certain metamorphic rocks, such as talc slate and mica slate, in North America, and sometimes in nodules or concretions in stratified rocks; in the latter case, *Apatite* is usually regarded as of organic origin.

It is remarkable that *Apatite* is never found to consist of pure phosphate of lime; there is always a certain proportion of chloride of calcium, and fluoride of calcium, combined with the phosphate of lime; the fluoride and chloride together usually amount to 8 per cent. of the whole, the phosphate of lime being 92 per cent.

B. *Turquoise*.—This well known and highly prized stone is an hydrated phosphate of alumina, with sometimes a minute trace of copper; it is found amorphous, in cavities and veins of several

rocks, as Lydian stone and sandstone. The most valuable specimens are procured from Arabia and Persia. Its colour varies from a sky blue to a verdigris green. *Turquoise* has the following composition :—

One atom of Phosphoric Acid, . . .	71	. . .	32.4 per cent.
Two atoms of Alumina, . . .	103	. . .	47.0 „
Five atoms of Water, . . .	45	. . .	20.6 „
	<hr/>		<hr/>
	219		100.0
	<hr/>		<hr/>

C. *Vivianite*.—This mineral is an hydrated phosphate of iron, usually produced by the decomposition and metamorphism of the iron sulphurets; it is found in veins traversing clay slate, and also in turf bogs and tertiary clays. Its crystals are monoclinic, and generally found in thin flexible laminæ. I have seen most beautiful crystals of *Vivianite*, found in the cavities of the bones of the *Cervus megaceros*, dug out of the Irish bogs. This mineral has been also found in New Jersey, U. S., forming pseudomorphs of oysters and belemnites. It has the following composition :—

One atom of Phosphoric Acid, . . .	71	. . .	31.3 per cent.
Three atoms of Iron Protoxide, . . .	84	. . .	37.0 „
Eight atoms of Water, . . .	72	. . .	31.7 „
	<hr/>		<hr/>
	227		100.0
	<hr/>		<hr/>

D. *Wavellite*.—This mineral is an hydrated phosphate of alumina, containing generally some fluoride of aluminium. It occurs in small, needle-shaped, radiating crystals, somewhat like *Prehnite* in appearance, and, like this mineral, it is generally of a greenish shade of colour. The following may be regarded as the typical constitution of *Wavellite* :—

Three atoms of Phosphoric Acid, . . .	213	. . .	35.9 per cent.
Four atoms of Alumina, . . .	206	. . .	34.8 „
Eighteen atoms of Water, . . .	162	. . .	27.3 „
Fluoride of Aluminium ($\frac{1}{3}$), . . .	11	. . .	2.0 „
	<hr/>		<hr/>
	592		100.0
	<hr/>		<hr/>

Wavellite is named after its original discoverer, Dr. Wavell, who found it in clay slate, near Barnstaple, in Devonshire, and it was subsequently discovered in carboniferous rocks of the same age, near Clonmel and Cork. It has been found, also, in various parts of Germany, in the United States, and in Brazil; and although a rare mineral, seems to be very generally distributed. Like *Turquoise*, it owes its origin to the metamorphic action of phosphoric acid upon clay.

16. The Nitrates.—Two important nitrates are found in the mineral kingdom—the nitrate of potash, and the nitrate of soda.

A. Nitre, or Saltpetre.—This salt is pure nitrate of potash; it is trimetric, and its crystals are prismatic, and usually thin and needle-like; it has the following composition:—

One atom of Nitric Acid, . . .	64	. . .	57.6	per cent.
One atom of Potash, . . .	47	. . .	42.4	„
	<hr/>		<hr/>	
	111		100.0	
	<hr/>		<hr/>	

Nitre is found in the caverns of several limestone districts, in Calabria and Ceylon; as an efflorescence from the surface of the ground in hot weather after rain, in Aragon, Hungary, Hindostan; and also as a constituent of certain mineral springs.

B. Nitratine, or Chili Saltpetre.—This salt is rhombohedral; and as it is pure nitrate of soda, its occurrence in the rhombohedral, or hexagonal system, adds another proof to those we already possess, serving to show that potash and soda are dimorphous in their modes of crystallization; it has the following composition:—

One atom of Nitric Acid, . . .	64	. . .	67.4	per cent.
One atom of Soda, . . .	31	. . .	32.6	„
	<hr/>		<hr/>	
	95		100.0	
	<hr/>		<hr/>	

Nitratine is found in granular crystals mixed with sand, associated with gypsum, rock salt, and glauber salt, at many places on the coast of Chili; and in the district of Tarapaca, the dry pampas for forty leagues, at a height of 3300 feet above the sea, is covered with beds of this salt several feet in thickness; together with gypsum, rock salt, and glauber salt, with recent sea shells, indicating that the whole deposit must be regarded as a raised sea beach, and therefore of marine origin.

17. **The Carbonates.**—The Carbonates of lime and magnesia are the most important minerals of this family; under the names of *limestone* and *dolomite*, they form large rock masses, which owe their origin to the action of currents of water distributing the particles of which they are composed over the floor of the ocean, according to mechanical laws.

A. *Calcespar*.—This important mineral is a carbonate of lime, having the following composition:—

One atom of Carbonic Acid, . . .	22	. . .	44 per cent.
One atom of Lime,	28	. . .	56 „
	<hr/> 50		<hr/> 100

Calcespar is rhombohedral or hexagonal in its crystallization, and several of its forms are represented in Figs. (30, 31, 32, 33). When found in rock masses formed by the mechanical agency of water, and often altered by subsequent metamorphic action, it receives the names of *limestone*, *marble*, *chalk*, *oolite*, *pisolite*, &c.

As a rock mineral, *calcespar* stands next to *quartz* in importance, as forming, next to it, the largest rock masses found in the crust of the earth.

B. *Talcespar*.—This mineral, when pure, is rather rare; and is generally found associated with *serpentine*. It is a carbonate of magnesia, having the following composition:—

One atom of Carbonic Acid, . . .	22	. . .	52.4 per cent.
One atom of Magnesia, . . .	20	. . .	47.6 "
	<hr/> 42		<hr/> 100.0

C. *Dolomite*.—This mineral is a double carbonate of lime and magnesia, having the composition—

Two atoms of Carbonic acid, . . .	44	. . .	47.8 per cent.
One atom of Lime, . . .	28	. . .	30.4 "
One atom of Magnesia, . . .	20	. . .	21.8 "
	<hr/> 92		<hr/> 100.0

Dolomite is named in honour of the illustrious geologist Dolomieu, and occurs under two distinct geological conditions—either forming veins traversing other rocks, or interstratified with them mechanically by the action of water. In the first case, it is supposed to owe its existence to volcanic agency, and in the latter, to aqueous influences.

When crystallized, its several varieties are known to mineralogists by the terms—*bitterspar*, *pearlspar* (with curved faces); *brownspar*.

D. *Spathic Iron Ore*.—This is a carbonate of protoxide of iron, having the composition—

One atom of Carbonic Acid, . . .	22	. . .	38 per cent.
One atom of Iron Protoxide, . . .	36	. . .	62 "
	<hr/> 58		<hr/> 100

This mineral, which forms one of the most valuable of the ores of iron, occurs under three distinct conditions:—

1. *Sparry Iron Ore*; forming the matrix of metallic lodes.
2. *Sphaerosiderite*; occurring in spheroidal, fibrous, radiated concretions; often found in trap rocks.

3. *Clay Ironstone*; found as nodules in the shales of the coal measures, and in the clay beds of other geological deposits. Its value as an ore of iron consists in the facility with which it can be reduced by the action of a blast furnace, and in its freedom from sulphur and phosphorus, which prove very detrimental to other ores of iron.

E. *Zincspar, or Calamine*.—This is the most valuable of all the known ores of Zinc, and has the following composition:—

One atom of Carbonic Acid, . . .	22.0	. . .	35.2	per cent.
One atom of Oxide of Zinc, . . .	40.5	. . .	64.8	„
	<hr/> 62.5		<hr/> 100.0	

This mineral occurs in metalliferous lodes containing *Blende*, or sulphuret of zinc, and is evidently the result of the metamorphic action of the carbonic acid of the air and water upon this mineral. When much *quartz* is present in the lodes, as is frequently the case, the sulphuret of zinc is transformed, not only into *Zincspar*, or carbonate, but also into an hydrated silicate of zinc, which resembles *Zincspar*, and is called *Calamine* by miners, although it is very inferior as an ore to the true *Calamine* or carbonate of zinc. Both ores were known to the ancients under the name of *lapis calaminaris*.

F. *Aragonite*.—This is a carbonate of lime, containing some carbonate of strontites; and crystallizing in the trimetric, instead of the hexagonal system. Its crystals are usually columnar and radiating in clusters, and are generally of a wine yellow colour.

Aragonite is found associated with *gypsum*, in beds of clay, at Molina and Valencia, in Aragon; and in clefts and cavities of trap rocks, in Bohemia and Antrim; it is also the form of carbonate of lime commonly found in fossil belemnites. It is said that cold springs containing carbonate of lime deposit crystals of

Calcespar; but that hot springs containing the same substance deposit *Aragonite*.

G. *Trona*.—This mineral is an hydrated carbonate of soda, having the following composition:—

Three atoms of Carbonic Acid, . . .	66 . . .	40.2 per cent.
Two atoms of Soda, . . .	62 . . .	37.8 „
Four atoms of Water, . . .	36 . . .	22.0 „
	<hr/> 164	<hr/> 100.0

Trona is found in broad, columnar, monoclinic crystals, and sometimes in fibrous aggregates. It forms an independent rock at Figzan, in North Africa, in the rainless district, and houses even are said to be built of this mineral by the natives. In parts of Peru, also, in the rainless regions, it forms crusts on the ground, as at Maracaibo; and it is found as an efflorescence, like nitre, near Sweetwater River, in the Rocky Mountains, associated with rock salt and glauber salt.

The *Trona*, or *Nether*, of the Hebrews, is twice mentioned in Holy Scripture, and is in both cases translated by the term *Nitre*, which is singularly inappropriate, as there is internal evidence, from the effervescence alluded to in the first passage, and the cleansing properties assigned to nitre in the second, that it is the *Carbonate* of an alkali that is meant. The passages are as follows:—

“As vinegar upon *nitre*, so is he that singeth songs to an heavy heart.”—Prov. xxv. 20.

“For though thou wash thee with *nitre*, and take thee much soap, yet thine iniquity is marked before me, saith the Lord God.”—Jer. ii. 22.

H. *Carbonates of Copper*.—There are two remarkable carbonates of copper known to the mineralogists, by the names of *Malachite* and *Azurite*; and to the miner, by the terms, *Green* and

Blue Copper. They are true ores, for they are found only in lodes, and never in bedded rocks, and are formed by the action of air and water containing carbonic acid, upon the sulphurets of copper, originally deposited in the lode.

(a.) *Malachite.*—This is an hydrated carbonate of copper, of a fibrous crystallization, encrusting the walls of the lode in a Stalactitic manner. It is always of a green colour, varying from emerald to verdigris and applegreen, and has the following composition:—

One atom of Carbonic Acid,	22	. . .	19.9	per cent.
Two atoms of Oxide of Copper,	80	. . .	72.0	„
One atom of Water,	9	. . .	8.1	„
	<hr/>		<hr/>	
	111		100.0	
	<hr/>		<hr/>	

(b.) *Azurite.*—This is an hydrated carbonate of copper, of a composition different from that of *Malachite*, being—

Two atoms of Carbonic Acid,	44	. . .	25.5	per cent.
Three atoms of Oxide of Copper,	120	. . .	69.3	„
One atom of Water,	9	. . .	5.2	„
	<hr/>		<hr/>	
	173		100.0	
	<hr/>		<hr/>	

Azurite is found in nature under the same circumstances as *Malachite*, and is often associated with it. It is of a bright azure blue colour when pure; but when mixed with earthy matter, is of a smalt blue, and liable to be mistaken for *Vivianite*.

Malachite is found in the largest masses known in the mines of Prince Demidoff, at Nischni Tagilsk in the Ural Mountains, on the West Coast of Africa, and at the Burra Burra Mines in South Australia. It takes a high polish, though soft, and when in large masses is cut into tables, snuff boxes, vases, and other articles of furniture.

Azurite has been used, occasionally, as a blue paint, but is of

little value, in consequence of its tendency to turn green, by conversion into malachite.

18. The Chlorides and Fluorides.—Chlorine and Fluorine form a few combinations with metals that are worthy of being noticed in an elementary sketch of the mineral kingdom.

A. Rock Salt.—Monometric, and always found in cubical crystals (Fig. 2); generally of a yellowish or reddish colour, rarely blue or green; lustre vitreous; transparent. It is a chloride of sodium, having the composition—

One atom of Chlorine, . . .	35.5	60.7 per cent.
One atom of Sodium, . . .	23.0	39.3 „
	<hr/>	<hr/>
	58.5	100.0
	<hr/>	<hr/>

Rock Salt is met with as an independent rock in sedimentary formations of all ages, and is unquestionably a marine product, deposited in consequence of the drying up of ancient sea beds. It is found in solution in sea water, which contains two and a half per cent of it. It occurs in the Steppes, in the sands of the Desert, in inland springs and lakes, and finally as a sublimation in the craters of volcanoes.

B. Fluor Spar.—Monometric; sometimes found in octahedral forms, but most usually in the cubical (Figs. 2, 4). Colour blue, yellow, green, &c.; lustre vitreous; transparent, translucent, or opaque. It is a Fluoride of Calcium, and has the composition—

One atom of Fluorine,	19	48.7 per cent.
One atom of Calcium,	20	51.3 „
	<hr/>	<hr/>
	39	100.0
	<hr/>	<hr/>

Fluor Spar occurs most frequently in the earthy matrix of metallic lodes, and delights especially in being associated with *Galena* and *Barytes*. It has been found as an accessory mineral

in the Dolomite of St. Gothard, and is sometimes found in cavities of sandstones, or filling the casts of fossils in limestone.

C. Cryolite.—This remarkable mineral is a double Fluoride of Sodium and Aluminium ; having the following composition :—

Six atoms of Fluorine, . . .	114.0	. . .	54.2	per cent.
Two atoms of Aluminium, .	27.5	. . .	13.1	„
Three atoms of Sodium, . .	69.0	. . .	32.7	„
	<hr/>		<hr/>	
	210.5		100.0	
	<hr/>		<hr/>	

This mineral is semitransparent, and greyish white in colour ; it is remarkable for its easy fusibility, and has been called Ice-stone, because it melts in the flame of a candle. It is supposed to be trimetric, because all its cleavage planes are rectangular, but its crystalline system is not known with certainty, because it is always found massive.

Cryolite is found at Arksutfiord, in West Greenland, where it was first discovered by Sir Charles Giesècke, in two veins in gneiss ; and it forms the matrix for Galena, Copper pyrites and Spathic iron. It has been also found at Miask, in the Ural Mountains associated with Fluorspar, Lithia-mica, and another double fluoride or aluminium and sodium, called *Chiolite*.

19. The Sulphurets and Arseniurets.—These minerals, together with the closely allied Seleniurets and Antimoniurets, are generally believed by mineralogists to have their origin deep in the interior of the earth, and to be sublimed thence into fissures or metallic lodes, by the agency of the interior heat of the globe. When deposited in lodes, and surrounded by the matrix of earthy minerals usually found associated with them, they form the basis of all the metallic ores that are quarried from the ground, and are variously changed by the metamorphic action of air and water into carbonates, sulphates, arseniates, &c. Among the most important of these valuable minerals may be mentioned the following :—

A. *Realgar*, or *Red Orpiment*.—This mineral is monoclinic, of resinous lustre, and of aurora red, or orange yellow colour; and is transparent or translucent. It is a sulphuret of arsenic, having the following composition :—

Two atoms of Sulphur, . . .	32 . . .	70.1 per cent.
One atom of Arsenic, . . .	75 . . .	29.9 „
	<hr/> 107	<hr/> 100.0

Realgar is found in the mines of Hungary, associated with ores of silver and lead; at St. Gothard it is found imbedded in Dolomite; and it was known to Strabo and Theophrastus under the name of Sandaraka. It has been used as a paint from very early times.

B. *Orpiment*.—This mineral is trimetric, with a pearly lustre, and lemon yellow colour. Like the last, it is a sulphuret of arsenic, but has a different composition, namely—

Three atoms of Sulphur, . . .	48 . . .	39 per cent.
One atom of Arsenic, . . .	75 . . .	61 „
	<hr/> 123	<hr/> 100

Orpiment is found in the same localities, and under the same circumstances, as *Realgar*, and, like it, has been used as a paint from very early times. Its name is a corruption of the Latin *aurigmentum*, or *golden paint*.

C. *Stibnite*.—This is a sulphuret of antimony, and constitutes the principal ore of that valuable metal. It is trimetric, and generally columnar, radiated. Its lustre is metallic, and its colour is lead grey. It has the following composition :—

Three atoms of Sulphur, . . .	48 . . .	28.2 per cent.
One atom of Antimony, . . .	122 . . .	71.8 „
	<hr/> 170	<hr/> 100.0

Stibnite, or Grey Antimony, is found in metallic lodes, and occasionally in beds, associated with spathic iron ore; it is usually accompanied, in lodes, by Blende, Barytes, and Quartz. It forms the source of nearly all the antimony of commerce, the crude antimony of the shops being formed by the simple fusion of the ore. The term *Antimony* applied to this ore, which was anciently called *Stibium*, is derived from a singular story recorded of the alchemical German monk, Basil Valentine, in the early part of the fifteenth century. This experimental philosopher, having thrown some crude antimony to the hogs, observed, that after it had purged them heartily they immediately fattened; and therefore, he imagined, his fellow monks would be the better for a like dose. His experiment, however, succeeded so ill, that they all died of it; and the medicine was, thenceforward, called *Antimoine*.

Stibnite was called by the Greeks *στίμμι*, or *πλατυόφθαλμον*, because it was used by women to blacken the eyebrows, so as to increase the apparent size of the eye. It was prepared for this purpose, by enclosing it in a lump of dough, and then burning it in the coals till reduced to a cinder. It was then extinguished with milk and wine, and again placed upon coals and blown till ignition; after which the heat was discontinued, lest it should “become lead;” from this statement of Pliny it appears that the ancients occasionally reduced antimony by accident, and mistook it for lead.

D. Silver Glance.—This mineral is a sulphuret of silver; it is monometric, and frequently occurs in arborescent and reticulated forms; it has a metallic lustre, and blackish lead grey colour, and is opaque.

Its composition is—

One atom of Sulphur,	. . .	16	. . .	12.9 per cent.
One atom of Silver,	. . .	108	. . .	87.1 „
		<hr/> 124		<hr/> 100.0

This valuable ore of silver is found in Saxony, Norway, and Hungary in Europe; and in Mexico and Peru, in the Americas.

E. *Erubescite, or Horse-flesh Copper Ore*.—This mineral is a double sulphuret of copper and iron; it has a metallic lustre, and when freshly broken has a colour between copper red and pinchbeck brown; from this circumstance it is usually called Horse-flesh, or Liver-coloured Copper Ore; it loses this peculiar colour quickly, and assumes an iridescent or variegated appearance, from which it is often called Variegated, or Purple Copper Ore. It is a most valuable ore of copper, and has the following composition:—

Three atoms of Sulphur, . . .	48 . . .	23.7 per cent.
Four atoms of Copper, . . .	127 . . .	62.5 „
One atom of Iron, . . .	28 . . .	13.8 „
	<hr/> 203	<hr/> 100.0

F. *Galena*.—This is the most common and most important of the ores of lead; it is monometric, and found usually in combinations of the cube and octahedron, as in Fig. 8; lustre metallic; colour lead grey. It has the following composition:—

One atom of Sulphur, . . .	16.0 . . .	13.4 per cent.
One atom of Lead, . . .	103.5 . . .	86.6 „
	<hr/> 119.5	<hr/> 100.0

Galena, when free from silver and antimony, exhibits always a cubical cleavage, and is called potter's lead by the miners; when silver is present, the *Galena* becomes granular in texture, like the cross fracture of cast steel, and the ore is said to be argentiferous; and when antimony is present the *Galena* assumes a massive streaked form, due to the fibrous and radiating crystallization of the *Stibnite* present. *Galena* is usually associated in its lodes with *Barytes* as a matrix, and not uncommonly

with *Fluorspar*. The most important lead mines are those of Linares, in Spain, Bleiberg, in Carinthia, and Cumberland, in England.

The following minerals are formed by the metamorphic action of air and water upon Galena :—

- (a.) *Cerussite*, or *white lead*.—Carbonate of lead.
- (b.) *Pyromorphite*.—Phosphate of lead, containing chloride.
- (c.) *Mimetene*.—Arseniophosphate of lead, containing chloride.

G. *Blende*.—This mineral is a sulphuret of zinc, and is the basis from which all the ores of that metal are derived; it is monometric, and affects chiefly the tetrahedric forms of that system; its lustre is resinous; colour brown, yellow, black, red, or green; translucent; fracture conchoidal. It has the composition :—

One atom of Sulphur,	16.0	. . .	33 per cent.
One atom of Zinc,	32.5	. . .	67 „
	<hr/> 48.5		<hr/> 100

Blende is found in metallic lodes, frequently associated with *Galena*; but, like the latter, is also met with occasionally in bedded rocks, under conditions showing that it was deposited by wet processes; as, for example, when it is found lining the cells of Ammonites, in the formations of the age of the Brown Jura and Lias. It is called *Black Jack* by miners, and the variety containing gold, found in the Brazils, is called *Jackotinga*. *Blende* gives origin, by metamorphic action, to the following minerals :—

- (a.) *White Vitriol*, or Sulphate of Zinc.
- (b.) *Zinc Spar*, or Carbonate of Zinc.
- (c.) *Calamine*, or hydrated Silicate of Zinc.

H. *Copper Glance*.—This is one of the ores called Grey Copper by miners; it is trimetric, and as such readily distinguished from the other ore called Grey Copper, which is always tetrahe-

dric in form ; lustre metallic ; colour blackish lead grey. It has the composition—

One atom of Sulphur,	16.0 . . .	20.1 per cent.
Two atoms of Copper,	63.5 . . .	79.9 „
	<hr/>	<hr/>
	79.5	100.0
	<hr/>	<hr/>

I. *Cinnabar*.—This valuable ore is the source of the mercury of commerce ; it is a sulphuret of that metal ; rhombohedral in crystallization ; colour, cochineal red, often inclining to brownish red, and lead grey. It has the following composition :—

One atom of Sulphur,	16	13.8 per cent.
One atom of Mercury,	100	86.2 „
	<hr/>	<hr/>
	116	100.0
	<hr/>	<hr/>

Cinnabar occurs in beds in slate rocks, and rarely in granite or porphyry ; it is found in the mines of Idria in limestone, and often replaces the casts of fossils in that locality. The most important mercury mines in Europe are those of Idria, and Almaden in Spain.

K. *Magnetic Pyrites*.—This is a sulphuret of iron, and occurs in the hexagonal system ; it has a metallic lustre ; colour between bronze yellow and copper red ; fracture small subconchoidal ; is slightly attracted by the magnet, and liable to rapid tarnish. It has the composition—

One atom of Sulphur,	16	36.4 per cent.
One atom of Iron,	28	63.6 „
	<hr/>	<hr/>
	44	100.0
	<hr/>	<hr/>

This mineral is found but rarely in crystals, and generally occurs in masses, filling fissures in granitic or metamorphic rocks. It frequently contains sulphuret of nickel in addition to the iron,

and is readily distinguishable from *Iron Pyrites* by its softness.

L. *Iron Pyrites*.—This well-known mineral is monometric, and is found in a crystalline form known as the *Pyritohedron*, which is the nearest approach known in the mineral kingdom to the Euclidean Dodecahedron (Fig. 6). The *Pyritohedron*, however, is not a true pentagonal dodecahedron, for the pentagons forming its faces have one side longer than the other four, which are equal. It is formed, geometrically, from the *Pyramidal Cube* (Fig. 9), by producing its alternate faces so as to obliterate the others. It is often found in single imbedded crystals, but more frequently massive. It has a metallic lustre, and is of a bronze yellow to gold yellow colour. It has the following composition :—

Two atoms of Sulphur,	32	. . . . .	53.3 per cent.
One atom of Iron,	28	. . . . .	46.7 „
	<hr/> 60		<hr/> 100.0
	<hr/>		<hr/>

Pyrites is found in beds among slate rocks, and is also met with massive in lodes. It is used as an ore of sulphur, and employed largely in the manufacture of sulphuric acid. When roasted in a reverberatory furnace it gives off sulphurous acid, and the roasted ore is reduced to the state of *Magnetic pyrites*, from which no further sulphur can be obtained by the process of simple roasting.

Pyrites is so hard that it readily strikes fire with steel, and it may thus be distinguished, by its hardness, from *Magnetic pyrites* and *Copper pyrites*, both of which somewhat resemble it in colour and appearance. The most valuable mines of *Pyrites* are those of Wicklow in Ireland. The name (*πυρίτης*) was given to this mineral in consequence of its striking fire when struck with steel, and not in consequence of its burning when exposed to fire. Some mines of *Pyrites*, as those of Pestarena, on the south of Monte

Rosa, contain minute traces of metallic gold ($\frac{1}{30000}^{\text{th}}$); the *Pyrites* in such cases is called *auriferous*, and is worked in search of the noble metal.

A variety of Iron pyrites, trimetric in its crystals, is called *Marcasite*, or *White iron pyrites*.

M. Coppernickel.—This remarkable mineral forms the chief source of metallic nickel, and is so named from its colour, which is copper red, with a grey or blackish tarnish; it occurs in hexagonal crystals, but is usually found massive, and accompanies various ores of copper and silver. It has the following composition:—

One atom of Arsenic, . . .	75 . . .	55.9 per cent.
Two atoms of Nickel, . . .	59 . . .	44.1 „
	<hr/> 134	<hr/> 100.0

Coppernickel is found in some of the mines of the St. Austell district, in Cornwall, where the little girls (called *Bal-maidens*) that dress the ore are obliged to use leather gloves, to protect their hands from the painful sores likely to be caused by particles of the arseniuret forcing themselves under their nails.

N. Nickel Glance, or White Nickel.—This mineral is monometric, and occurs in *Pyritohedrons*; it has a metallic lustre; and silver white or steel grey colour, often tarnished greyish black. It is a compound sulphuret and arseniuret of nickel, having the composition—

Two atoms of Sulphur, . . .	32 . . .	19.3 per cent.
One atom of Arsenic, . . .	75 . . .	45.2 „
Two atoms of Nickel, . . .	59 . . .	35.5 „
	<hr/> 166	<hr/> 100.0

Such is the theoretically perfect composition of *Nickel Glance*, when pure; but in practice it is found that a portion of the nickel is always replaced by cobalt and iron.

O. *Cobalt Glance*.—This mineral has a composition similar to that of Nickel Glance; it is monometric, and occurs especially in the combinations of the octahedron and pentagonal dodecahedron, which have twenty faces formed of isosceles triangles, and are the nearest approach made in nature to the Euclidean *Icosahedron* (Fig. 7), which is bounded by twenty equilateral triangular faces. It has the composition—

Two atoms of Sulphur, . . .	32 . . .	19.3 per cent.
One atom of Arsenic, . . .	75 . . .	45.2 „
Two atoms of Cobalt, . . .	59 . . .	35.5 „
	<hr/> 166	<hr/> 100.0

This ore and the following, commonly called *Grey Cobalt*, constitute the principal sources of Cobalt in commerce.

P. *Smaltine, or Grey Cobalt*.—This ore is monometric, like the other arseniurets of cobalt and nickel, and is generally found in cubical combinations; its colour is from tin white to steel grey, sometimes iridescent or greyish from tarnish. It has the following composition:—

One atom of Arsenic, . . .	75.0 . . .	71.8 per cent.
One atom of Cobalt and Nickel, . . .	29.5 . . .	28.2 „
	<hr/> 104.5	<hr/> 100.0

This mineral forms an ore of cobalt or of nickel, according to the preponderance of one or other of these metals in its composition, and generally also contains some iron replacing both. In its various changes the quantity of arsenic remains nearly constant—a circumstance due to the fact that the atomic weights of cobalt, nickel, and iron, are nearly the same; being, in fact, $29\frac{1}{2}$, $29\frac{1}{2}$, and 28. When the cobalt preponderates, the mineral is called *Smaltine*; and when nickel predominates, it is called *Cloanthite*; when both disappear, or nearly so, an arseniuret of

iron is left, which is called *Leucopyrite*, and occurs in a different crystalline system, having become trimetric. *Leucopyrite* has the composition—

One atom of Arsenic,	75	. . . .	72.8 per cent.
One atom of Iron,	28	. . . .	27.2 „
	<hr/> 103		<hr/> 100.0

Leucopyrite has a silver white colour, merging into steel grey, with a metallic lustre; it is found as an accidental mineral in many rocks, especially serpentine, and in metalliferous lodes.

Q. Mispickel.—This mineral is an arsenio-sulphuret of iron, having the same chemical composition as Nickel, or Cobalt Glance; viz. :—

Two atoms of Sulphur,	32	. . . .	19.6 per cent.
One atom of Arsenic,	75	. . . .	46.0 „
Two atoms of Iron,	56	. . . .	34.4 „
	<hr/> 163		<hr/> 100.0

Mispickel, therefore, bears the same relation to the glance ores of cobalt and nickel, that *Leucopyrite* bears to *Smaltine* and *Cloanthite*. It is trimetric like *Leucopyrite*, instead of monometric, as the corresponding ores of cobalt and nickel are; and this fact serves to show that iron, although capable of replacing nickel or cobalt, atom for atom, is not isomorphous with those metals. *Mispickel* is generally found in short prismatic or tabular crystals, singly imbedded, or attached in groups; also massive, in granular or fibrous aggregates; colour silver white, inclining to steel grey; lustre metallic. *Mispickel* is frequently met with in veins of ore, and is also an accessory ingredient in many crystalline schists and also in serpentines.

R. Copper Pyrites.—This well-known and most valuable ore of Copper is a double sulphuret of copper and iron, having the following composition :—

Four atoms of Sulphur, . . .	64.0 . . .	34.9 per cent.
Two atoms of Copper, . . .	63.5 . . .	34.6 „
Two atoms of Iron, . . .	56.0 . . .	30.5 „
	<hr/> 183.5	<hr/> 100.0

Copper Pyrites is monometric, and affects chiefly the Octahedric and Tetrahedric forms of that system; it has a metallic lustre, and is of a brass yellow colour, liable to tarnish readily, and often iridescent.

Copper Pyrites, or *Yellow Copper Ore* forms the principal ore of Copper found in Cornwall, where upwards of 150,000 tons of this ore are raised annually; it is associated in several mines of that county with *Tinstone*, *Erubescite*, *Copper Glance*, *Galena*, *Grey Copper Ore*, and *Blende*. No metallic mineral is liable to more changes, from the metamorphic action of air and water, than *Copper Pyrites*. The following are several of the products of this metamorphic action, which takes place incessantly in lodes:—

- (a.) *Blue Vitriol*.—Hydrated sulphate of Copper.
- (b.) *Malachite*.—Hydrated carbonate of Copper.
- (c.) *Chrysocolla*.—Hydrated silicate of Copper.
- (d.) *Black Copper Ore*.—Oxide of Copper.
- (e.) *Limonite*.—Hydrated oxide of Iron.

S. Grey Copper Ore.—This complex and variable ore is easily recognized by its tetrahedric form, whenever it occurs in crystals; so much so, indeed, as to occasion the name *Tetrahedrite*, often given to it by mineralogists; it has a metallic lustre; colour between steel grey and iron black; rather brittle, with uneven subconchoidal fracture.

There is no ore of copper or silver known that is more complex or variable in composition than *Grey Copper Ore*. It consists essentially of four atoms of a basic sulphuret, combined with one atom of an acid sulphuret.

The basic sulphurets may be any combinations or proportions of the following :—

1. Copper Glance.
2. Erubescite.
3. Silver Glance.
4. Magnetic Pyrites.
5. Blende.
6. Cinnabar.
7. Galena.

while the acid sulphurets are always—

1. Stibnite.
2. Orpiment.

This remarkable ore, therefore, may contain sulphur, arsenic, antimony, mercury, zinc, iron, silver, and lead. The most important varieties of this mineral are those in which copper, silver, or mercury, preponderate; they are called, respectively—

1. Grey Copper Ore (Kupfer fahlerz), 37 per cent. Copper.
2. Argentiferous Grey Copper Ore (Silber fahlerz), 10 to 30 per cent. Silver.
3. Spaniolite (Quecksilber fahlerz), 7 to 16 per cent. Mercury.

The *Grey Copper Ore* found in the Cornish Mines is very valuable as an ore of Copper, but is rarely argentiferous; the most valuable of the argentiferous ores are found at Freiberg, and other parts of Germany; while the mercurial varieties are known in Hungary and several parts of the Tyrol.

T. *Ruby Silver*.—This ore is found in crystals, of the rhombohedral form, and hexagonal; its lustre is metallic or semi-metallic; colour black, sometimes approaching cochineal red; fracture conchoidal. It is a double sulphuret of antimony and silver, analogous in composition to the *Grey Copper Ore*, but much less complex; its composition is—

Six atoms of Sulphur, . . .	96 . . .	17.7 per cent.
One atom of Antimony, . . .	122 . . .	22.5 „
Three atoms of Silver, . . .	324 . . .	59.8 „
	<hr/> 542	<hr/> 100.0

Ruby Silver is found associated with *calc spar*, *native arsenic*, and *galena*, at Andreasberg, in the Hartz; in Mexico it is worked extensively as an ore of silver, and is not uncommon.

U. *Light Red Silver*.—This mineral is closely related to *Ruby Silver*, differing from it in the fact that arsenic replaces the antimony; it is rhombohedral and hexagonal in crystallization; lustre adamantine; colour cochineal red to aurora red; subtransparent; fracture conchoidal, uneven.

It has the following composition :—

Six atoms of Sulphur, . . .	96 . . .	19.4 per cent.
One atom of Arsenic, . . .	75 . . .	15.1 „
Three atoms of Silver, . . .	324 . . .	65.5 „
	<hr/> 495	<hr/> 100.0

There are many other double sulphurets, or sulphur salts, as they are called, known to mineralogists, but not of much importance in practice. One of the most beautiful of these is *Bournonite*, which is a sulphuret of antimony, combined with a sulphuret of copper and lead; and there seems to be no limit to the number of *antimonio-sulphurets* and *arsenio-sulphurets* that may have been formed by sublimation, and mutual decomposition, under favourable circumstances in lodes. The combinations already described will, it is hoped, give the learner an introduction to the important subject of metallic sulphurets.

20. **The Native Elements.**—Many of the simple bodies known to chemists occur in the Mineral Kingdom perfectly pure, and are called “native” by mineralogists. Among the native elements, the noble, or imperfectly oxidisable metals, are commonly found; and also elements, as sulphur and carbon, that in their pure state, are probably the result of mutual chemical decomposition of complex bodies, either mineral or organic.

A. *Native Gold*.—This metal always occurs native; it is monometric, and found chiefly in octahedral and dodecahedral

crystals, and in pyramidal cubes (Figs. 4, 5, 9, 11); its physical characters are so well known as to render description unnecessary.

Native Gold always contains some silver, up to 10 per cent., and frequently copper, mercury, and iron. It is found in alluvial detritus, spread over many countries in gravel, either in "grains" or in "nuggets," and is separated from the surrounding rock, mechanically by washing, and chemically by amalgamation with mercury, which possesses the property of dissolving gold. In ancient times gold was found probably in the detritus of most countries, but its occurrence is at present confined to the diluvial drift of countries, like California, Australia, &c., in which the earlier inhabitants were not sufficiently civilized to have learned the art of working it, from its original deposits. When *gold* occurs in metalliferous lodes, it is generally associated with *iron pyrites*, and it is not improbable that all the gold now usually found in gravel beds existed originally in lodes of *iron pyrites*.

B. *Native Platinum*.—This metal is monometric, and has been found, though rarely, in cubes (Fig. 2); it is generally combined with *iron*, *iridium*, and other metals; it is found in alluvial gravel, like *gold*; and was originally discovered in Brazil, where it received its name, *platina*, the diminutive of *plata* (silver); in the Brazils, it is associated with *iridium*, *rhodium*, *osmium*, *palladium*, *gold*, *copper*, and *chromium*. It was subsequently found by the Russians, in large quantities, in the Ural Mountains, and was used by them for some time in the manufacture of coins. When *platinum* contains much *iridium* and *palladium*, as is frequently the case, it is called by mineralogists *platiniridium*, which occurs sometimes, like pure *platinum*, in cubes with truncated angles.

C. *Native Quicksilver*.—Mercury is often found in small fluid globules scattered through the matrix in which *cinnabar* is found; it is always the result of the decomposition of this mine-

ral, probably by the intervention of organic substances. It is called monometric, because it freezes at 39° below zero into octahedric crystals. *Mercury* forms, with *native silver*, a mineral called *Amalgam*, containing two atoms of mercury to one atom of silver; and occurring in crystals which are modifications of the rhombic dodecahedron.

D. *Native Silver*.—This metal is sometimes found native, and is then believed to be produced by a metamorphic reducing agency, influencing the sulphurets or other ores of silver; it is monometric, and usually found, like the corresponding mineral, *native copper*, in filiform or arborescent masses, or plates filling natural planes in the matrix.

E. *Native Copper*.—This mineral is generally octahedric, or in pyramidal cubes, when it occurs in crystals, and is commonly found in arborescent or flattened masses, like *native silver*. This remarkable mineral has been found in large masses in serpentine and trap rocks, in Cornwall at the Lizard, and on the shores of Lake Superior at Point Keweenaw.

In addition to the native metals already mentioned, the following have been found frequently:—

F. *Native Iron*.—In meteoric masses, associated with *Nickel*.

G. *Native Lead*.—Formed by desulphuration of *Galena*.

H. *Native Tin*.—Associated with *gold* in Siberia.

I. *Iridosmium*.—Alloy of *iridium*, and *osmium*.

K. *Native Tellurium*.—Found in Hungary with gold.

L. *Native Bismuth*.—Found with ores of silver, cobalt, &c.

M. *Native Antimony*.—Associated with silver ores.

N. *Native Arsenic*.—Found with *antimony*, *iron*, *silver*, *gold*, and *bismuth*.

O. *Native Sulphur*.—This substance is found in trimetric crystals, usually pyramidal, and clustered together in cavities; or in fibrous radiating masses.

Sulphur is found as an accessory in rocks, and as a separate

formation in beds. It is formed directly by sublimation in the fissures of volcanoes, and in the neighbourhood of burning coal beds. It is generally, however, formed by the desulphuration of metallic sulphurets, or of sulphuretted hydrogen in springs. It is remarkable that the artificial crystals of sulphur formed by the chemist, are monoclinic, while the natural crystals are always trimetric.

P. Native Carbon.—This element is found “native” under three different forms, as *Diamond*, *Graphite*, and *Anthracite*.

(*a.*) *Diamond.*—Occurs in the monometric system, frequently in the forms of the *six-faced Octahedron*, or *Tetrahedron* (Figs. 13, 14), with curved faces and edges; it has a watery lustre, but is occasionally tinged yellow, red, orange, green, brown, or black. The *diamond* consists of pure carbon crystallized, and it is remarkable that Newton conjectured, from its high refractive power, that it was combustible; it is totally consumed at a high temperature (14° of Wedgwood’s pyrometer), and converted into carbonic acid gas. It is usually found in regions that furnish a laminated, talcose, sandstone rock called *Itacolumite*, from the name of the locality in Brazil where the connexion between this matrix rock and the diamond was first noticed by mineralogists. *Itacolumite* sometimes passes into flexible sandstone, and has been found in the Brazils, in North Carolina, in the Ural, and near Delhi in Hindustan. There is little doubt that the *diamond* in all cases is formed in a sandstone rock resembling *Itacolumite*, and that it owes its existence to organic causes. It is generally found loose in the soil, having been washed, by atmospheric agency, from its original nidus in the sandstone rock.

The diamonds found in the Brazils are associated with *gold*, *platinum*, *magnetic iron*, and *rutile*. In the Ural workings the diamonds are found associated with gold. In India, diamonds are found in sandstone between Hyderabad and Masulipatam, where the famous Kohinoor was produced.

Diamonds are usually weighed by carats ($3\frac{1}{6}$ grs.), and increase in value enormously with increase in weight. The following may be mentioned as instances of remarkable diamonds:—

The largest diamond of which we have any record is that described by Tavernier as belonging to the great Mogul. It was found A. D. 1550, in the mine of Colone, and, in its rough state, weighed 900 carats, but was reduced in cutting it to $272\frac{1}{2}$ carats.

The Kohinoor, or “Mountain of Light,” became the property of the Queen of England on the annexation of the Punjaub in 1850. It is reputed to be 4000 years old; and it is certain that in 50 A. C. it belonged to the Rajah of Mjayin, and remained in the possession of his successors until the Mahomedans conquered India. The Kohinoor is mentioned by Tavernier A. D. 1665, as the property of the Great Mogul. Its original weight was 793 carats, and it has been reduced by repeated cuttings to its present weight, which is only $103\frac{3}{4}$ carats. It is thought that the original rough form of the Kohinoor was that of a rhombic dodecahedron (Fig. 11), and that this great mass was broken accidentally into three parts, forming the Kohinoor, the Russian diamond, and the Dorianoor, or “Ocean of Light.”

The Russian diamond weighed 194 carats, and was sold for £90,000, and an annuity of £4000.

The Kohinoor and Dorianoor formed part of the plunder seized by Nadir Shah, at the taking of Delhi in 1739, when the treasures carried off exceeded £70,000,000 in value.

(b.) *Graphite*, or *Plumbago*.—Occurs in the hexagonal system, usually in six-sided, thin tabular, or short prismatic crystals; also massive, in radiated, lamellar, or compact aggregates; colour iron black to grey; streak black, with metallic lustre; soils paper; used for pencils to draw and write with. It consists of carbon, with some iron in combination as a carburet of iron.

Graphite is sometimes found, as in Eastern Siberia, forming beds in the metamorphic crystalline rocks, and is believed to be

the result of the metamorphosis of coal beds. It also occurs as an accessory in the trap rocks, as at Borrowdale, in Cumberland; and in gneissose beds in Greenland.

(c.) *Anthracite*.—This term expresses the varieties of coal that do not contain bitumen. All coal beds are the product of vegetation, and are formed in the localities where the plants grew. Coal consists principally of carbon, with more or less of bitumen, and a small quantity of silica and alumina, and sometimes peroxide of iron; potash and soda have been frequently found in it, and are, no doubt, the remains of the alkaline salts of the growing plants. The varieties of coal that contain bitumen are the following:—

- (a'.) *Pitch, or Caking Coal*, burns with a yellow flame, and requires frequent stirring to prevent its caking; colour velvet, or greyish black.
- (b'.) *Cherry Coal*; burns more rapidly than *pitch coal*, and being more brittle, breaks up readily, so as to require less stirring.
- (c'.) *Splint Coal*; is a hard and dry kind of *cherry coal*, passing into *cannel coal*.
- (d'.) *Cannel Coal*; has a dark greyish black or brownish black colour; a large conchoidal fracture, and takes a good polish. It burns with a clear yellow flame, without melting, and has been used as a substitute for candles, from which circumstance it derives its name.
- (e'.) *Jet*; resembles *cannel coal*, but is blacker, and has a more brilliant lustre. It is found in detached pieces in clay, near Whitby and elsewhere. *Jet* was called *Gagas* by the ancients, from the name of a river in Lycia, at the mouth of which it was found, and many virtues, medicinal and otherwise, were attributed to it.

Anthracite has a bright, submetallic lustre; iron black colour, often iridescent; it is opaque, and has a conchoidal fracture; no

varieties of coal are called anthracite that contain less than 90 per cent. of pure carbon. *Anthracite* occurs in many coal beds, especially in Pennsylvania, South Wales, Leinster, and parts of Saxony and Russia.

21. Organic Compounds.—Among the mineral substances, whose origin is clearly organic, the following may be noticed :—

A. *Bitumen*.—This has been already mentioned as forming the chief distinction between ordinary *coal* and *anthracite*. Many different oily and pitchy substances are included under the term *bitumen*, of which the most important are *naphtha* and *asphalte*.

(a.) *Naphtha*.—A volatile and colourless oil with bituminous smell; it is frequently mixed with paraffine and other substances, especially *asphalte*; when quite pure, its composition is as follows :—

Six atoms of Carbon,	36	. . .	88 per cent.
Five atoms of Hydrogen,	5	. . .	12 „
	<hr/> 41		<hr/> 100

(b.) *Asphalte*.—This may be described as a hardened mineral pitch, not containing oil; it is massive, and has a conchoidal fracture; colour pitch black; opaque, lustre resinous; when rubbed, gives out a bituminous odour; is easily ignited, and burns with a bright flame and thick smoke.

Naphtha, under the name of *Rock oil*, is found in natural wells in many places; as Persia, Pennsylvania, Canada; where it is believed to impregnate the sandstones and other rocks in which it is found, in consequence of its natural distillation from coal beds, by virtue of subterranean heat.

Asphalte, or *mineral pitch*, is found, under similar circumstances, in the Dead Sea, in Trinidad, and elsewhere. It is also found in limestones in Ireland and other countries, as the result of the destructive natural distillation of fossil shells, and even in

granites, as at Poldice, in Cornwall; and in a bed of gneiss, thirty yards thick, at Nullaberg, Sweden. It is said, also, to have been detected in meteoric stones.

B. *Amber*.—This mineral is found under circumstances similar to those under which *jet* is worked, in rounded masses in clay; with, frequently, insects and fragments of plants enclosed in them; it has a yellow colour, with pencillings; lustre resinous; is translucent or transparent, and becomes electric on being rubbed. It has the following composition:—

Ten atoms of Carbon, . . .	60	83.3 per cent.
Four atoms of Hydrogen, . .	4	11.1 „
One atom of Oxygen, . . .	8	5.6 „
	<hr/>	<hr/>
	72	100.0
	<hr/>	<hr/>

Amber is a fossil gum resin, produced by conifers of the tertiary period; it is found in the upper chalk beds of Lemberg, and in pebbles washed from the tertiary beds on the south shore of the Baltic, and the coasts of Yorkshire and Essex.

C. *Mellite*.—This mineral, also called *Honeystone*, occurs in dimetric crystals, pyramidal, and imbedded singly in crystals having the form shown in Fig. 19; colour, honey yellow to wax yellow; seldom white; lustre resinous; semitranslucent.

Mellite is an hydrated compound of an organic acid, called mellitic acid, with alumina; and mellitic acid itself is composed of four atoms of carbon and three atoms of oxygen (i. e. equal parts of both). *Mellite* has the following composition:—

Three atoms of Mellitic Acid, .	144.0 . .	40.3 per cent.
One atom of Alumina, . . .	51.5 . .	14.4 „
Eighteen atoms of Water, . .	162.0 . .	45.3 „
	<hr/>	<hr/>
	357.5	100.0
	<hr/>	<hr/>

Mellite occurs frequently in lignite, or *brown coal*; and is found in Moravia, Thuringia, Bohemia, and Greenland.

PART II.

THE VEGETABLE KINGDOM.

“VEGETABILIA—Corpora organisata et viva, non sentientia.”

“*Regnum Vegetabile* vivens superficiem vestit, radiculis bibulis terrena haurit; foliis obvolitantibus ætherea respirat; calidâ metamorphosi declaratur in festivales nuptias generantes dispergenda intra præscriptas stationes semina.”—*Linnaeus*.

CHAPTER III.

ORGANS OF PLANTS.

MINERALS, according to the famous definition of the greatest of all naturalists, are “*corpora congesta* ;” whereas plants are “*corpora organisata et viva*.” The mineral possesses a definite shape and definite chemical composition, and simply grows by the aggregation of particles of the same kind continually added from without; the plant, on the other hand, possesses organs and life; all its parts are not of the same kind, some being appropriated to one use and some to another; and it possesses life; or has a commencement and a termination of its individual existence, during which it produces other living things, which survive it, and perish in their turn, having previously produced others to take their place, and hand on to future ages the representatives of the individual. It is necessary, therefore, to the complete study of plants, that we should understand their organs, and study their life. The description of the organs of plants is called vegetable

anatomy, or *organography*; and the study of these organs in action, or in their living state, is called vegetable physiology. These two subjects, together with a brief account of the classification of plants, will be sufficient for an elementary treatise.

1. **The Plant Type.**—If we inquire into the history of any tree or plant, we shall find some such record as the following:—A seed, produced by some pre-existing tree or plant, was placed in the ground, and commenced to grow, by pushing downwards into the ground a radicle or rootlet, and pushing upwards into the air, one, two, or more seed leaves, or cotyledons;* from the axis, or intersection of these seed leaves, the ascending stem of the plant continued to grow, throwing out fresh leaves in its ascent, and also branches; at the same time, the root descending into the ground, threw out other rootlets; and repetitive this process, characteristic of vegetation, was continued until the small seed had grown into the giant tree, spreading out its myriads of arms, covered with leaves, and piercing the ground beneath by roots and rootlets sufficiently strong and extensive to form an anchorage power to prevent the tree from falling, either by its own weight, or in consequence of the pressure of the wind upon its surface. In this process we observe three classes of organs—*root, stem, leaf*.

By the *roots* our plant is held firmly in the ground, and sucks up nourishment from the salts and organic matters dissolved in the moisture that surrounds them.

The *leaves* absorb certain gases and give out others into the air, performing the double office of *respiring* and *digesting* the matters conveyed to them from the ground.

The *stem* serves the purpose of the great communicating

* Κορυλήδων.—A cup-shaped organ, like the socket of the hip-joint, or the suckers on the arms of the cuttle-fish.

organ between the roots and leaves; it encloses and protects the numerous canals that convey the crude food from the roots to the leaves, and others that reconvey the digested sap from the leaves, to be deposited in the various parts of the plant in which growth proceeds.

Our type plant now possesses organs of *absorption*, *respiration*, *circulation*, *digestion*, and consequently grows by an organic process, and not as a mineral, by the constant addition of identical molecules by chemical affinities; but it also possesses the fatal gift of *life*, and must therefore *die*, after a period long or short, as the great Creator wills. A mineral never dies; it may be decomposed and converted into other minerals, but it is continually reproduced again by the action of the chemical and crystalline forces that first produced it. Our plant, however, being a living thing, must die, and its growth must have a limit. The individual plant only dies, for the *type plant* is continued by the process of *reproduction*, which belongs essentially to living things. For this purpose, certain portions of our plant are set apart, which are called *flowers*, or organs intended for the production of seeds. When the seeds are formed, the function of the old plant is fulfilled, and sooner or later it perishes, giving place to the younger plants produced from its own seeds; and these plants in their turn produce their seeds, and die.

Such is the lot of all living things, and it seems impossible for us to regard it without sorrow, whether it be that it contradicts our own instinctive yearning for immortality, or that our finite faculties cannot comprehend the Creator's wisdom.

Our plant is composed of organs of *nutrition*, *respiration*, *reproduction*, and its life consists in the suitable exercise of all these functions. The organs themselves are the *roots*, the *stem*, and branches, the *leaves*, and the *flowers*, and these compound organs are themselves composed of molecular elements and tissues which must be first described.

2. **Cellular Tissue.**—A microscopic examination of the minute structure of plants shows us that it is ultimately composed, either of rounded ellipsoidal *cells*, or of elongated *fibres*, which are closed vessels, and form the ultimate molecules of a plant. The *cells* are shown in Fig. 34, and the *fibres* in Fig. 35.

The whole structure of young plants, and

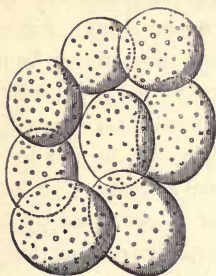


Fig. 34.

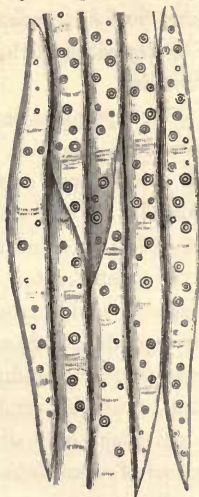


Fig. 35.

of mosses and other vegetables of the lowest grade, even when full grown, is made up of *cellular tissue*; but this fabric is too tender and brittle to give the needful strength and toughness to large plants, in which, therefore, it is always more or less replaced by *woody fibre*, which, from the elongated form of its elementary cells, and the superior toughness of the *lignine* of which its cell walls are composed, is better calculated to form the framework of the stems and branches of the larger plants and trees.

The cells of which the young plant is composed have the power of subdividing themselves, so as to form two cells out of one, each cell having its enclosing wall complete; and it is by this process that growth is carried on, each cell that is so produced being capable, up to a certain limit, of again subdividing, and of growing in bulk. Thus, vegetable growth consists essentially of two things :

- (a.) The expansion of each cell, until it reaches its full size, which is generally $\frac{1}{400}$ th of an inch in diameter.
- (b.) The multiplication of the cells in number, by the mysterious process of *fission* or subdivision, which continues as long as the plant grows.

The cells, as they grow, build up the tissues or fabric of the plant, which is thus ultimately composed of minute closed sacs filled with various fluid or semifluid substances; and if the cells were not capable of changing their shapes by mutual pressure, there would occur in the plant a number of intercellular spaces or vacuities, as in a pile of cannon balls, the total volume of which might bear a very sensible proportion to the space filled by the cells themselves. We find, however, that the cells in contact behave like a number of soap bubbles, and form plane walls dividing them from each other, like the cells of bees. This appearance is shown in Figs. 36, and 37; in the former of which

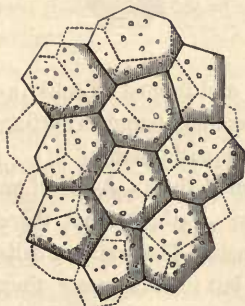


Fig. 36.

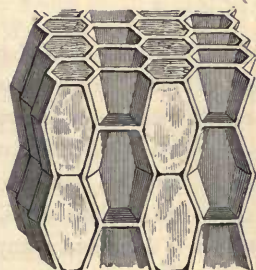


Fig. 37.

it will be observed that a pentagonal structure predominates, and in the latter, an hexagonal.

If the cells were originally perfect spheres, and altered in shape by mutual pressure, they would always take on the forms of some one or other of the five Euclidean solids; and, accordingly, we observe in the cells of plants, under the microscope, in many cases, the *tetrahedron*, Fig. 1; the *cube*, Fig. 2; the *dodecahedron*,

Fig. 6; but never, so far as I know, either the *octahedron* or the *icosahedron*. When the *cells*, as often happens, are cylindrical in form, instead of spherical, their mutual pressure produces hexagonal forms, as in Fig. 37, which are terminated, sometimes as in the figure, by flat ends, and sometimes by rhombic trihedral extremities; in this latter case, the cell assumes the shape of the rhombic dodecahedron (Fig. 11).

The intercellular spaces are generally small, as compared with the whole mass of cellular tissue; but they sometimes form regular tubes or *air passages*, as shown in Fig. 38, and may be

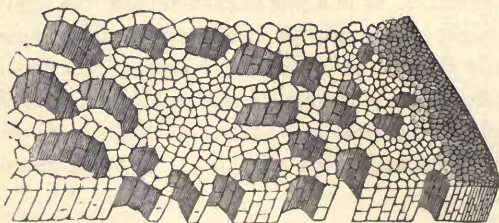


Fig. 38.

compared to chimneys placed in stacks, and formed of cells instead of bricks. Such *air passages* are commonly found on cutting across the stems and leaves of marsh and aquatic plants.

The size of *cells* in plants varies from $\frac{1}{30}$ th to $\frac{1}{1000}$ th of an inch in diameter, the ordinary size being $\frac{1}{400}$ th, so that there may be 100 millions of cells in a cubic inch. The walls of cells are at first thin, and always colourless, but in many cases they become thicker by additions made continually on the inner side, and this process sometimes continues until the cell becomes perfectly solid. The cells while young and living are always closed, some parts of their walls being, however, thinner than others, but there are no actual pores opening from one cell into the others; and yet the sap and all the juices of the plant are readily carried up and down, from one end of the plant to the other, by means of these closed cells, by the action of the molecular forces called *endosmose* and *exosmose*, by natural philosophers.

Whenever two cavities are separated by an animal or vegetable membrane, and contain fluids differing from each other in physical and chemical properties, it is found that the fluids pass from one cavity into the other, according to laws depending on their composition, and especially on their density. Now, the action of the sun and air upon the leaves of plants tends constantly to alter the density and composition of the contents of the cells exposed to its influence, and so creates a molecular force extending from cell to cell, from the remotest leaf down to the deepest rootlet of the plant. These molecular forces are found sufficient to cause the ascent of the sap, and to produce the distribution of the concocted juices to every organ of the plant requiring their supply and nourishment.

3. **Woody Fibre.**—Wood cells, shown in Fig. 35, differ from ordinary cells, in their elongated *fusiform* shape, and in having thicker walls; and, from their shape, they admit more readily than spheroidal cells of intercellular spaces, which in woody fibre are called *ducts*, or *vessels*. Wood consists of bundles of woody fibre, and of ducts variously intermingled, which run lengthwise through the roots and stem, and terminate in the veins of the leaves. In wood cells, the thickening of the wall takes place from the inner side, according to regular laws, certain spots or pores, placed opposite each other in the adjoining cells, not being thickened, but retaining their original coating, through which the sap and juices pass from cell to cell. This structure is shown in Fig. 39, which requires no further explanation. It must be remembered, that the wood cells do not form a connected system of pipes opening into each other, so as to convey an unbroken stream of sap through the plant. The sap is compelled to ascend from



Fig. 39.

cell to cell, by small molecular forces, so that in mounting through a single foot it has often to pass through upwards of 2000 partitions.

The regular canals or *ducts* found in the intervals of woody fibre are formed by the fusion of perpendicular rows of cells placed end on, which, by the absorption of their terminating walls, become converted into continuous tubes of more or less considerable length. These vessels or ducts are variously marked on their inner surface, and have received names from botanists, depending on these marks, the uses and origin of which are very imperfectly known. The following kinds of *ducts* are recognized:—

- (a.) *Spiral Ducts*.—Represented in Fig. 40.
- (b.) *Reticulated Ducts*.—Shown in Fig. 41.
- (c.) *Annular Ducts*.—Fig. 42.
- (d.) *Scalariform Ducts*.—Fig. 43.
- (e.) *Dotted Ducts*.—Fig. 44. These are the ducts most com-



Fig. 40.



Fig. 41.



Fig. 42.

monly found in the woody tissue of *Exogenous* plants; and they are

marked by pits or dots, in the same manner as the wood cells shown in Figs. 35 and 39.

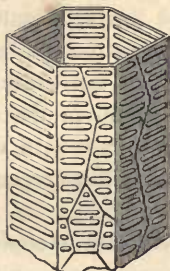


Fig. 43.



Fig. 44.

Spiral vessels are found in the youngest parts of the plants in which they occur; and are abundantly developed in young woody tissue, and in the petals of flowers.

Annular vessels pass frequently into the former, and generally occur later, and in the same situations. This is the commonest form of vessel in the *Equisetaceæ*.

Reticulated vessels occur in succulent roots, stems, and petioles of *Endogenous* plants, and are generally of large size, as compared with other classes of ducts.

Scalariform vessels are especially characteristic of the woody tissue of *Ferns* and *Clubmosses*, and are generally altered into hexagonal tubes by the lateral pressure of the surrounding cells.

4. **The Seed.**—The ancient maxim, *omne vivum ex ovo*, applies to plants as well as to animals; we place a seed in the ground, it grows up into a tree, bears flowers and fruit containing seeds like the original, and then dies, allowing its likeness or type to be perpetuated by the seeds it has formed. The circle is complete, commencing and ending with a seed; and we may obtain the simplest and clearest idea of plant life, by studying it from the seed placed in the ground, through all its modifications and

changes, until we arrive at the formation of the fresh seeds, which are to recommence the process of germination once again.

If we examine, in spring, the germinating seed of *mignonette*, or other plant used for the experiment; we shall perceive that it throws up into the air two tiny seed leaves, mounted upon a little stem, having little rootlets at its extremity; and, upon moistening and opening a seed itself, we can easily recognize that this tiny plant pre-existed, folded up in the seed from which it sprang. The very first step, therefore, in vegetation, consists in the simultaneous production of three organs—a *root*, a *stem*, and *leaves*.

The leaves so produced are called *seed leaves* or *cotyledons*, and



Fig. 45.



Fig. 46.

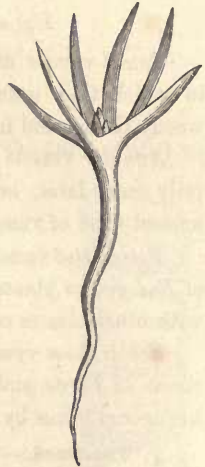


Fig. 47.

plants are classified according to important varieties occurring in their seed leaves.

1. Monocotyledons (having one seed leaf), Fig. 45.
2. Dicotyledons (having two seed leaves), Fig. 46.
3. Polycotyledons (having many seed leaves), Fig. 47.
4. Acotyledons (having no seed leaves), Fig. 48.

The rudimentary plantlet contained in the seed is called an *embryon*; its little stem is called the *radicle*, its seed leaves are called *cotyledons*, and the little bud of undeveloped leaves at its summit is called the *plumule*. Thus the plant, a few days old, is an epitome of the tree or herb; it has a *stem*, from the lower end of which *roots* strike downwards: it has *leaves*, which perform the office of digestion and respiration; and it has a *stem*, which expands upwards, forming new leaves to continue the offices of digestion and respiration on a scale suited to the increased size of the organism.



Fig. 48.

At its first commencement of growth, the young plant derives its nourishment from the fleshy substance of the *cotyledons*, or from other stores of albuminous food laid up in various parts of the seed; but becomes capable of providing for itself, as soon as the cotyledons have assumed the form of green leaves, or as soon as the budding plumule has developed such: for now the rootlets derive mineral nourishment from the ground, which is carried by the ascending sap into the leaves, where it is digested by the action of air and light, and forms the material from which fresh cells are formed and growth continued; and as soon as this stage is reached the seed leaves die, having finished their task, and the plant enters upon a new stage of its existence, deriving all its nourishment from the ground, and elaborating it into higher forms of matter, by the joint influence of light, air, and life in its leaves.

The food stored up for the young plant in the cotyledons was likened by the older botanists to the yolk of an egg, while that stored up in the mass of the seed, around the embryo, but not forming part of its substance, was compared to the white of the egg.

5. **Buds.**—There are many trees, shrubs, and herbs, whose whole life consists in a repetition of the process of growth just

described. The stems of such plants rise by a simple shaft, carrying a terminal bud on its extremity, by the continued evolution of which the plant grows, as it originally grew from the plumule of its seed. Some *Exogens*, such as *Cycas*, and many of the *Endogens* plants grow in this fashion, the *Yucca*, the *Cocoa nut palm*, and the *Banana*; these are shown in Fig. 49.



Fig. 49.

(a.) *Cycas*.(b.) *Yucca*.(c.) *Cocoa nut palm*.(d.) *Banana*.

In trees and herbs that have branches the vegetation is carried on, not merely by terminal buds, but also by axillary buds, which produce the branches in the same manner as the main stem itself was produced. These buds are called *axillary*, because they are produced in the *axilla*, or angle formed between the leaf and the stem; and wherever a leaf grows on the stem of a plant or tree, there exists, what pompous old Dr. Johnson would have called, had he been a botanist, the *potentiality* of forming a bud

and branch. *Buds*, whether terminal or axillary, lengthen into branches by the same process as the original stem from the plumule of the embryo; and the only difference between the plumule and the bud consists in this, that the plumule is furnished by the seed leaves with its first store of nourishment to sustain it until able to seek its own food; while the bud, being fixed on a growing stem, and in direct communication, by its system of vessels, with the ascending sap, requires, in general, no such aid as that of cotyledons, but grows at once from the stem, as soon as the warmth of returning spring sets the sap in motion, and gives the first impulse to vegetation. Some French botanists have, therefore, given to the bud the name of *fixed embryo*.

As the main stem produces buds in the axils of its leaves, so also the branches produce buds; and if all the buds grew into branches, there would be as many as there are leaves, and they would be arranged with the same regularity; but this is not found to be the case, as comparatively few of the buds grow into branches, but remain in the condition called *latent buds*, ready, in case of emergency (such as the destruction of the terminal bud), to take on a rapid growth, and to replace the buds destroyed by accident. Gardeners take advantage of this property of latent buds, in the operation called “pollarding,” which consists in cutting off the upper part of the stem of willows or other trees, so as to cause the latent buds of the lower part of the stem to take on a sudden growth, and form the twigs required by the husbandman.

The various plants formed from plumule and buds may be thus classified—

A. *Herbs*, which die altogether, or die down to the ground, on the approach of winter, and are divided into—

- (a.) *Annuals*, which flower in the first year and die, root and all, after ripening their seed; e. gr. *Mustard*.
- (b.) *Biennials*, which grow the first season, without forming

flowers and fruit, survive the winter and flower the second year, and die, root and all, after ripening their seed ; e. gr. *Carrot*.

- (c.) *Perennials*, live and blossom year by year, dying down nearly to the ground each winter, leaving a portion of the stem with its buds, close to the ground, from which buds the plant of the following year is produced.

B. *Shrubs*, are perennial plants, with woody stems, which continue to live, without dying down year by year, and grow continually.

C. *Trees*, differ from shrubs only by their greater size.

The *bud*, as we have seen, is placed in the axil of the leaf, and destined to survive it and produce a branch in the following year ; it is therefore provided, in climates in which there is a severe winter, with a series of protecting scales, to which botanists have given a number of names (*tegmenta*, *perulæ*, *hibernacula*), and these scales are themselves defended against the cold and wet, by being often covered with downy hairs, or with a resinous paint. In warm climates, scales for the leaf buds are almost unknown, and the first leaves of the bud are as green and perfect as those subsequently formed.

Trees and shrubs may be divided into two classes, according to the mode of their summer growth from buds ; those which have a *definite* annual growth, and those which have an *indefinite* annual growth.

The *Horse-chestnut* and *Lilac* are good examples of trees with a *definite* annual growth. The horse-chestnut (Fig. 50, section) forms a strong terminal bud, at the end of each branch, flanked by two axillary buds, which are



Fig. 50.

more vigorous than the other axillary buds of the same branch. Consequently, in spring, almost the whole growth of the branch consists in the developement of these three buds, which contain in miniature the greater part of the stem, leaves, and flowers they are to produce during the season, and the whole work of vegetation takes place by a definite growth of a few weeks' duration, after which the terminal buds, and axillary buds for next year are formed, and protected by their scaly covering against the coming winter.

Most of the smaller plants grow *indefinitely*, that is, they grow during the whole summer, until they are checked by the autumnal frosts; they consequently produce no terminal buds, and the upper axillary buds are small and feeble, as compared with those formed in the earlier part of summer, on the lower ends of the branches. Such stems commonly die at the top in winter, and the growth of the succeeding year takes place mainly from the lower axillary buds. In such cases, there is no single main stem continued, year after year, in a direct line, but the trunk becomes lost in its branches, and the trees so formed have rounded or spreading tops. The common *Elm* forms an excellent example of a tree produced by *indefinite* annual growth.

6. The Skin, or Epidermis.—Before proceeding to a description of the organs of plants, it is necessary to say something of a structure that covers them all in common, whether they be root, stem, leaf, or flower. It was long thought by botanists that the skin or epidermis that covers the surface of a plant consisted merely of cellular tissue, somewhat thickened and hardened by exposure to the air; and this supposition is correct, as respects vegetables low in organization, such as seaweeds, mosses, and the like; but it is now well established that the epidermis is a separate structure, and is often very complex in its arrangements, especially on leaves.

On macerating a portion of the skin in water, it is found to consist of a thin structureless membrane (*cuticula*) stretched over

the whole outer surface, beneath which comes the epidermis proper, formed of cells placed in close contact, so as to allow of no intercellular spaces, except such as are specially provided, and called mouths (*stomata*); which are shown in Fig. 51, occupying the under surface of a leaf; and one of them is drawn in cross section in Fig. 52. The edges of the *stomata* are formed by two slightly curved cells,

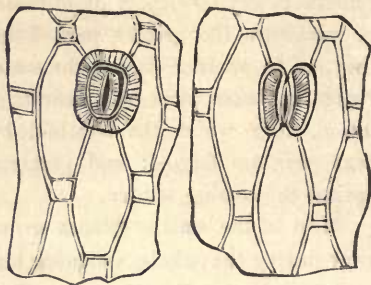


Fig. 51.

called *lips*, which open and close the aperture of the mouth, according to the degree of dampness or dryness respectively; and seem to regulate the transmission of vapour from the surface.

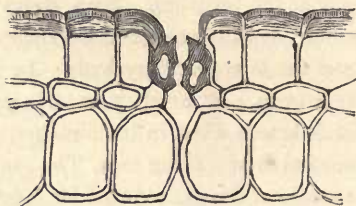


Fig. 52.

Stomata are found on all epidermis exposed to the air, except that of the roots; and especially on the under surfaces of the leaves of ordinary plants; in aquatic plants, whose leaves rest on the surface of the water, the *stomata* are reversed, and placed on the upper surface. The cross section of an ordinary leaf, placed with the lower surface upwards, is shown in (Fig. 53), in which we observe the *epidermal* layer of compact

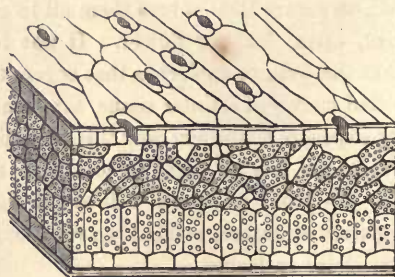


Fig. 53.

cells on the upper and lower surfaces furnished with *stomata* on the lower surface of the leaf ; inside the upper epidermis, at the bottom of the diagram, are seen a number of closely packed cylindrical cells, placed like brick pavement, with their narrow ends up, an arrangement calculated to diminish evaporation through the upper surface ; and in the lower half of the thickness of the leaf we observe a quantity of loosely packed cellular tissue, with large intercellular spaces, communicating directly with the external air, through the *stomata*, which cover extensively the under surface of the leaf. The process of respiration in the plant, which is the converse of that in the animal, takes place by means of the stomata and intercellular spaces of the leaves ; and at the same time the stomatic cells serve as valves, the opening and closing of which, by self-acting laws, regulate the evaporation that takes place from the surface.

The importance of these breathing pores may be estimated from the following facts :—In the *White lily*, there are 60,000 stomata to the square inch on the epidermis of the lower surface of the leaf, and only 3,000 in the same space of the upper surface. More commonly there are none at all on the upper surface. In different plants they vary from 1000 to 170,000 per square inch. In the *Apple* tree, where they are under the average as to number, there are 24,000 to each square inch of under surface, so that each leaf may be estimated to contain 100,000 breathing pores, whose numbers make up for their minuteness.

7. The Root.—The young plant, starting into growth from its embryo in the seed, sends a rootlet downwards into the earth, and a stem upwards into the air ; the point of separation of the ascending and descending stems was called by the older botanists the neck of the plant (*collum*), or vital node, and it was considered as the seat of life, and an importance attached to it which it by no means deserved.

The young *root*, like the young stem, consists at first of cellular tissue only, and grows by continuous additions to its point ; this cellular tissue is covered by a thin *epidermis*, unprovided with

breathing pores, which permits the absorption of moisture charged with salts from the ground. The structure of the growing extremity of the root is shown in Fig. 54, and also the arrangement of the cellular fibrils by which moisture is sucked up by the root from the interstices of the particles of soil. As the rootlet grows older, its epidermis thickens and becomes incapable of absorbing more moisture, an operation absolutely necessary for the nutrition of the plant, and one which is effected chiefly by the extremities of the new rootlets, and by the hairy processes sent out from their surface. Woody fibre is also developed in the root as it grows older, according to the same laws as in the stem, which will be presently described. This woody fibre gives strength and toughness to the old root, which is thus gradually diverted from its original purpose—that of absorbing food from the ground—to the purely mechanical, but no less important function, of anchoring the growing plant securely in the soil.



Fig. 54.

Roots are divided by botanists as follows:—

- (a.) *Simple primary root*.—This is sometimes called a main, or tap-root, from which small side branches, or rootlets, occasionally diverge, and is well illustrated by the common *Radish*, Fig. 55. In many trees, also, intended, like the oak, for large growth, the primary root takes the lead of the side branches, for many years, as a strong *tap-root*.
- (b.) *Multiple primary roots*.—These are roots, several of which start at once, or nearly so, from the seedling stem, and form a bundle or *fascicle*, in place of a simple main root.



Fig. 55.

- (c.) *Tuberous roots*.—Biennial and many perennial herbs accumulate in their roots a store of nourishment analogous to that laid up in the cotyledons of the seed and the early growth of the plant in the following season of spring depends mainly on the nourishment laid up in these adventitious roots, which are called *tubers*. In Fig. 56, an example of such roots is taken from the common *Dahlia*, in which the spring growth is supplied from these tubers, which die in the course of the summer, as they are emptied of their contents; but another set of tubers is produced during the autumn, to serve in turn as a storehouse of food for the succeeding season.



Fig. 56.

- (d.) *Secondary, or adventitious roots*, are produced, not from the primary radicle of the embryo, but from nodes, joints, or in general, *buds* of the primary stem, and are commonly met with in monocotyledonous plants, in which the radicle remains undeveloped. They are also necessarily the only kind of roots that can occur upon specimens of Dicotyledons raised, not from seed, but from cuttings, layers, tubers, &c. They arise from the side of the stem that produces them, and most commonly in the neighbourhood of buds and leaves.
- (e.) *Aerial roots* belong to plants called *Epiphytes*, or air plants, which grow upon other plants, but do not feed upon them in a parasitic manner, for they derive all their nourishment from the air, by absorption. Such roots belong, generally, to damp tropical climates, where the high temperature, and great moisture, facilitate their production, but they are occasionally met with in colder latitudes, in which they are employed, not for absorbing nourishment, but for the me-

chanical support of the plant, as is well seen in the rootlets of the common ivy, that enable it to climb, by shooting out from the sides and internodes of the stem.

8. **The Stem.**—The *stem* of a plant is the ascending axis, or that part of the trunk, which in the embryo grows in the opposite direction from the root, seeking the light, and exposing itself as much as possible to the air. It is the essential characteristic of the stem as distinguished from the root, that it shall produce leaves at certain definite and symmetrically arranged points called nodes, which are so called, because in many plants, such as *Grasses*, *Bamboos*, *Horsetails*, &c., the node forms a complete ring, dividing the stem into an upper and a lower portion; such stems are jointed at the point where the leaf grows, which is either single, or opposite, or whorled.

The spaces between the points at which leaves are produced are called *internodes*, and often correspond to the annual growths from buds already described.

Stems receive various names, according to their mode of growth, which is quite independent of their internal structure, to be described hereafter.

- (a.) *Culm.* This is the name given to the jointed stem of endogenous plants, such as *Grasses*, *Bamboos*, &c.
- (b.) *Caudex.* This term is usually applied to any persistent, erect, unbranched form of main stem, such as the *Palm tree*, or *Tree fern*.
- (c.) *Sucker.* This is the name of a branch of subterranean origin, which, after running horizontally, and emitting roots in its course, at length rises out of the ground, and forms an erect stem. Subterranean modifications of the stem, as might be expected, are often confounded with varieties of the root, but are all reducible to a few simple types.

They are always distinguishable from roots by their property of producing buds, which is inherent in the stem, and is never

found in a true root. The following varieties, more permanent than the *Sucker*, are recognized:—

- (d.) *The Rootstock, or Rhizome.* This is a perennial, horizontal, subterranean form of stem, which grows from year to year, like an ordinary stem, by a terminal bud, and emits roots from the under side of its nodes.
- (e.) *The Tuber.* When the rhizome enlarges at its bud, the expanded bud is called a tuber, which consists chiefly of a deposit of starch serving for the future development of the buds (*eyes*) involved in the growth of the tuber. The common *Potato* forms an excellent example of the tuber, regarded as a portion of a growing stem. The *tuberous stem* is distinguishable at sight from the *tuberous root* (Fig. 56), by its containing *buds*, which are never found in the true *root*.
- (f.) *The Bulb.* This is a permanently shortened stem, covered with scales, which are to be regarded as modified leaves. It can never be confounded with a root, even by a careless observer, and its structure is shown in one of its commonest forms, in Fig. 57 (*Lily*).

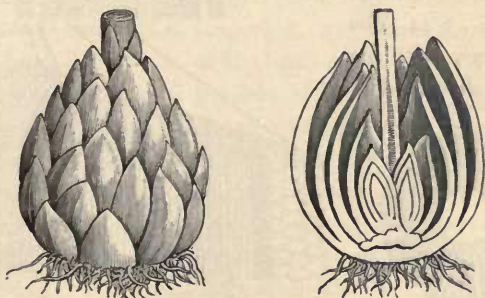


FIG. 57.

Plants are divided, according to the structure of their stems, into the following classes, which correspond with the classes formed from an examination of their seeds and mode of germination.

These classes are—

A. Exogens,	. . .	{ Polycotyledons.
		{ Dicotyledons.
B. Endogens,	. . .	Monocotyledons.
C. Acrogens,	{	Acotyledons.
D. Thallogens,		

A. *Exogens* are so called from the fact that their stems grow, year by year, by the addition of a fresh layer, or ring of new material, on the outer side of the former stem. If we examine the growth of a young exogen, or the growth of a current year's branch of any exogen, we shall find that the stem or branch consists at first altogether of cellular tissue ($\pi\alpha\rho\acute{\epsilon}\gamma\chi\upsilon\mu\alpha$); but as growth proceeds, some of the cells elongate into woody fibre ($\pi\rho\omicron\sigma\acute{\epsilon}\gamma\chi\upsilon\mu\alpha$), the cells of which are marked with transverse bars, or spiral lines, and so give rise to *ducts* or *vessels*, such as are shown in Figs. 40 . . . 44. The woody fibre, with its enclosed ducts, does

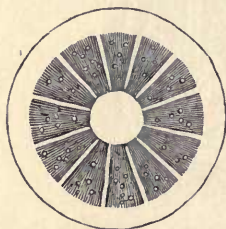


Fig. 58.

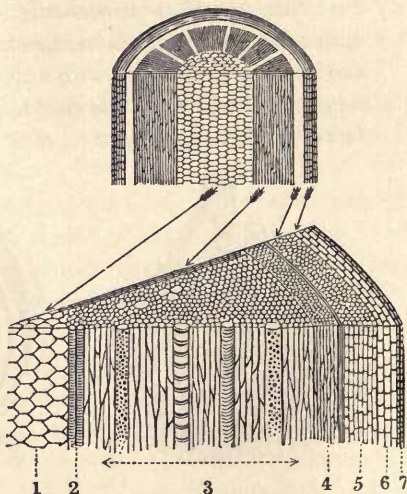


Fig. 59.

not form itself indiscriminately in any part of the cross section of the stem, but is produced in a ring midway between the centre and circumference of the stem. In this manner the year's growth

produces a woody zone, provided with vessels on the inner side especially, enclosing a central mass of cellular tissue, called the *pith*, and surrounded by another mass of cellular tissue called the *bark*. The woody zone so produced is not continuous, but is formed of wedge-shaped masses of woody fibres enclosing vessels, and these wedges of wood are separated from each other by thin vertical sheets of cellular tissue, called *medullary rays*, which connect the cellular tissue, or parenchyma of the *pith*, with the parenchyma of the *bark*; and outside the whole, the cuticle or epidermis is stretched. Figs. 58, 59, show the cross and vertical sections of an annual branch at the close of the season of growth, composed of central pith, surrounded by a zone of wedge-shaped masses of woody fibre and vessels, enclosed by another zone of cellular tissue, which is connected with the pith by medullary rays or sheets of parenchyma; and the whole is enclosed by its skin or epidermis.

The outer portion of the zone of woody fibre is considered as belonging to the *bark*, and is usually formed of woody fibres, longer, thinner, and tougher than those of the central stem; these are called *bast fibres*, or *bass fibres*. The textile and valuable fibres of hemp, flax, bass wood, and other plants, are all derived from this portion of the bark, which is called the *liber* (ενδοφλοίον); the central portions of the bark are called *green bark* (μεσοφλοίον), and consist of ordinary cellular tissue like the pith; and the outer layers below the epidermis, which in permanent stems is usually shed and replaced by them, consist of flattened cells, which are called the *corky layer* (επιφλοίον); this is the portion of the bark that acquires so great an importance in such trees as the Cork oak, Elm, and others.

At the close of the first season of growth, the cross section of the branch presents the following structures, counting from within, outwards (Fig. 59):—

1. The pith—cellular tissue.
2. The medullary sheath—spiral ducts.

3. The woody zone—woody fibres with ducts, annular and dotted.
4. The liber—bass fibres.
5. The middle bark—cellular tissue.
6. The Corky layer—flattened cellular tissue.
7. The Epidermis—flattened cellular tissue with stomata.

In addition to these structures, placed round each other in rings, the *medullary rays* form radiating, vertical sheets of cellular tissue connecting the pith and bark together, and forming the silver rays so conspicuous in the cross section of certain woods.

Let us now examine what occurs at the commencement of the second year of growth. It is found that the border ground, lying on the outer side of the woody zone, and the inner side of the liber, has become filled with a highly digested mucilaginous sap, containing all the elements proper for the formation of new cells and fibres, and called *plastic sap*, or *Cambium*, by the older botanists. This concocted sap corresponds to the *plastic lymph* of animal physiologists, and contains much dextrine; and as soon as the stimulus of returning spring is applied, it commences to lay down a fresh zone of woody fibres, abundantly provided with spiral vessels on the inner side, while the medullary rays are either prolonged by the addition of new cellular tissue, or new rays are formed to keep up the vital connexion between the pith and bark. Thus the wood grows, year by year, forming a fresh ring or zone each season, so that the age of a branch may be ascertained by counting the number of such rings or zones of which it is composed.

The *inner bark*, or *liber*, like the woody zone, continues to grow during the life of the tree, by yearly additions made to its inner surface each spring, from the *cambium*; and sometimes a cross section of the liber shows rings of growth as regular as those of the wood; but, more commonly, the successive deposits of liber are undistinguishable from each other.

The *middle bark*, composed altogether of cellular tissue, does not increase generally after the first year, and being shut out by the corky layer from the light, often quickly perishes, never to be renewed.

The *outer bark*, or corky layer, increases by the addition of tabular cells, for a few years, by additions made upon its inner surface; and in some trees, as the *Paper birch*, fresh layers of corky bark are added for many years, which readily exfoliate when dead, and give the tree its name.

From what has been already stated, it appears that in *Exogens* the woody central stem grows by additions made each season to its outer side, from the cambium cells, while the bark grows by additions made yearly from the cambium to its inner surface. The inner and older parts of the wood become thus, year by year, further removed from the active and living part of the stem, which is found chiefly in the *cambium zone*. For some time a vital connexion between the outer and inner woody layers is maintained by the medullary rays; but these become gradually choked up, together with the vessels of the older wood, by mineral matter imbibed with the water by the roots, and by the gradual thickening of the woody fibres, and consequent diminution of their internal capacity. The older zones of wood thus grow harder and darker in colour, and receive the name of *heart-wood* (*duramen*), while the newer and still bibulous layers of the outer zones are called *sapwood* (*alburnum*), and continue to carry from the rootlets to the leaves the crude sap, which is there digested, and then sent down through the vessels of the *liber*, to form the *plastic cambium*, from which the new cells, both of the woody stem and of the fibrous liber, must be produced.

The outer part of the bark, exposed to atmospheric and mechanical agencies, soon loses its vitality, and becomes as dead as the heart wood itself, so that in time the only living parts of an Exogen are—

- (a.) The summit of the stem and branches, with the buds that prolong them upwards and outwards, and develope leaves each year for the respiration and digestion of the tree.
- (b.) The fresh tips of the rootlets pushed forwards into the ground, from which they imbibe the mineral and organic food, which must be conveyed to the leaves for concoction.
- (c.) The outermost zone of wood, that carries the crude sap to the leaves; and the innermost zone of bark, that reconveys from the leaves the digested sap, to fill the cambium cells.

Thus it appears that the inner heart wood and pith of a tree may rot and die, and that the outer bark may also be destroyed or die; and yet that the tree will continue to live on, provided its cambium zone be uninjured, from which are produced, year by year, the additions made to the outer circumference of the wood, and to the inner circumference of the bark.

B. *Endogens*.—If we examine with a microscope the cross section of one of the wedges of young woody tissue, formed in the branch of a growing Exogen (Fig. 58), we shall find it to be composed, as shown in Fig. 59, from within, outwards, of the following tissues:—

1. Woody fibres, containing *spiral* vessels.
2. Woody fibres, containing *dotted* and *annular* vessels.
3. Woody fibres, longer and thinner than the others, forming the *bast* fibres, characteristic of the inner bark.

These wedges of variously constituted woody fibre are placed in rings or zones around a central pith of cellular tissue, and are surrounded by an exterior zone of cellular tissue, which forms the external bark, destitute of woody fibres. The elementary bundles of fibro-vascular tissue, which are arranged in wedge-like masses round a common centre in the Exogens, are, in the Endogens, plunged as if at random, through the mass of cellular tissue of which the stem is composed. In Fig. 60 is shown the vertical

section of an Endogen, or monocotyledonous plant, such as the common cane; and in Fig. 61 is shown the magnified section of



Fig. 60.

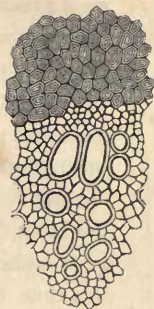


Fig. 61.

one of the fibro-vascular bundles of woody fibres that penetrate the cellular tissue of the stem in a vertical direction. These elementary bundles are always placed, with reference to the centre of the stem, in the same relative position as the regular wedges of woody tissue in the Exogens; that is to say, the *spiral* vessels are found in the woody tissue on the inner side, the *dotted* and *annular* ducts in the centre, and on the outer side occur the slender *bast fibres*, characteristic of the *liber* or woody bark of the Exogen. Instead, however, of being symmetrically arranged in zones of wedges, so as to form woody rings on the inner side, and a continuous bark on the outer side, as in the Exogens, these elementary bundles of woody fibre are unsymmetrically placed, and no regular bark surrounding the entire stem can be formed. The monocotyledonous plants were called Endogens by Daubenton, from an erroneous idea as to their mode of growth, which he conceived to take place in a manner the converse of the growth of Exogens. His idea of endogenous growth is illustrated by Fig. 62, which represents the fibro-vascular bundles rising inside each other at the centre, and promoting the growth of the tree,

like the sliding tubes of a telescope. According to this idea of the growth of an Endogen, the density of the outer layers of the



Fig. 62.

cross section of an Endogen is due simply to mechanical pressure, caused by the continued central evolution of new shoots to prolong the tree, and it is difficult to conceive how the young fibro-vascular bundles at the centre could be themselves protected from that pressure. The cross section of the lower part of the stem of a *cane* or *palm* (fig. 63) shows near the outer circumference a zone of darker coloured and more thickly set vascular bundles than can be accounted for by simple excentric pressure; for this dense zone is often separated from the outer rind by another

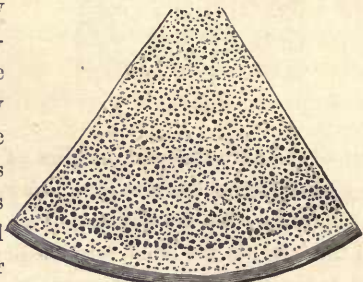


Fig. 63.

zone shown in the figure, in which cellular tissue (*parenchyma*) preponderates above the woody bundles as much, as it does in the central portions of the stem. If the density of the outer zone were simply due to mechanical pressure, the most dense portion of the stem should be that nearest the rind, which is not always the case, although it is sometimes so.

A careful examination of the course of the fibro-vascular bundles of Endogens led the botanist Mohl to the more correct view of their structure, shown in Fig. 64. The woody fibres are formed in all plants from the leaves, which send down the digested sap containing the *plastic cambium*, which deposits the new fibres and cells; and the course of these bundles of fibres in Endogens is, at first, towards the centre of the stem, producing the appearance

that misled Daubenton; but when their course is followed still further down the stem, they are found to diverge, much more slowly than they originally converged, until they ultimately reach the dark superficial zone shown in Fig. 63, where they either terminate in the *rind*, or *false bark*, or disappear altogether.

One of the largest vegetables on the globe is the Dragon tree of the Canaries (*Dracæna Draco*), allied to the *Asparagus* and *Lily*. It grows near Orotava, in Teneriffe, and in 1799 was found by Humboldt to measure 45 ft. in circumference ($14\frac{1}{3}$ ft. diameter). The great size of this enormous tree is mentioned by many of the older writers; and as early as 1402, it is described by Bethencourt, as large, and as hollow as it is now. Humboldt considers this particular Dragon tree and the Baobab of Senegal, described by Adanson, as the oldest plants now living. This Baobab is an exogen, and measures 78 ft. in circumference, and is considered by botanists to be 5000 years old (be the same more or less!) The *Dragon*

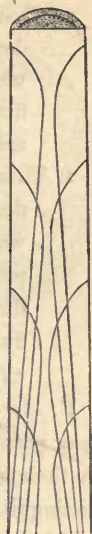


Fig. 64.

tree of the Canaries is hollowed out into a Lady Chapel, while the *Baobab* is excavated by the negroes as a place of sepulture for criminals, who are speedily converted into mummies by the dry, soft wood of which the trunk is composed.

It is worthy of remark, that the destruction of the interior of an endogen, without injury to the tree, effectually disposes of the old theory of its mode of growth, and proves that, like an exogen, its living parts consist of the new rootlets, the fresh leaves, and the vessels and ducts that carry the ascending and descending sap.

The true distinctions between the stems of *monocotyledonous* and *dicotyledonous* plants has never been better stated than by Desfontaines, who was the first to point out the difference between them. He says:—

Plants may be divided into two great classes, according to the structure of their stems.

1. Those that have no distinct concentric zones, whose density decreases from the circumference towards the centre, and whose pith (cellular tissue) is interposed between the fibrous bundles without diverging medullary rays; these are the *monocotyledons*.
2. Those that have distinct concentric zones, whose density decreases from the centre towards the circumference, whose pith is contained in a longitudinal canal with diverging medullary rays; these are the *dicotyledons*.

C. *Acrogens*.—These are *acotyledons* possessing fibrous woody tissue in their stems, by which they are distinguished from the *thallogens*, which consist altogether of cellular tissue, and have no stems properly so called. The most remarkable acrogens, are the *Tree ferns* of tropical climates, one of the most beautiful of which is shown in Fig. 65, which represents the *Alsophila* of the East Indies, which grows to a height of fifty feet. Amongst our own plants, acrogens are well represented by common ferns and club mosses (*Lycopodiaceæ*). In the structure of their stem, acrogens are readily distinguished from endogens and exogens.

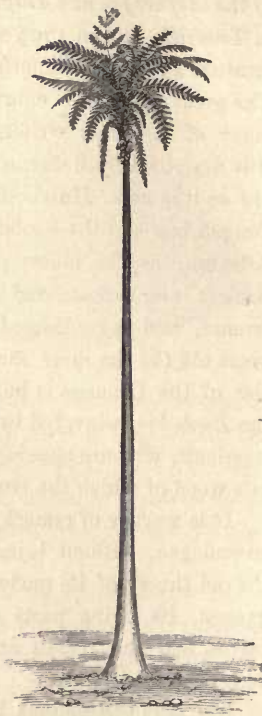


Fig. 65.

The typical structure of the stem may be understood from Fig. 66, which is the cross section of a tree fern (*Cyathea*) from the West Indies.

The woody fibro-vascular bundles (*prosenchyma*) form somewhat symmetrically shaped masses, which are placed in a single ring, surrounded by the pith or cellular tissue (*parenchyma*) that fills the remainder of the stem. The outer part of these bundles of *prosenchyma* is formed of woody fibres, shaded dark; and the central portion, more lightly shaded,

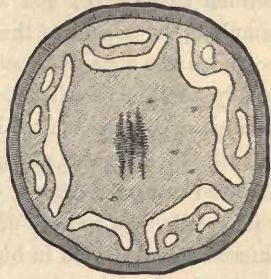


Fig. 66.

is occupied by woody fibres and vessels, which are always *reticulated* (Fig. 41), *annular* (Fig. 42), or *scalariform* (Fig. 43); and rarely *spiral* (Fig. 40), or *dotted* (Fig. 44). The reasons for these peculiarities in the vessels of plants are not known, but the fact itself is well established. The outer rind, or *false bark*, of the acrogens, is formed of the decayed leaf scales that belong to the leaves of past seasons.

The peculiar structure of an acrogenous stem may be studied by cutting across the lower part of the stem of the common *Brake fern* (*Pteris aquilina*), in which the dark lines forming the outer margins of the fibro-vascular bundles produce the appearance called by schoolboys "*King Charles in the Oak.*" Acrogens, like endogens, grow by a bunch of young leaves, formed each season at the top, and like them possess a constant thickness of stem; for it is a physiological law in botany, that the thickness of a stem is in direct proportion to the area of foliage; hence in exogens, as the foliage increases year by year, the stem must increase also; whereas in endogens and acrogens, as the surface of the foliage is always constant, the section of the stem must be also constant.

D. *Thallogens*.—These plants, like the acrogens, are *acotyledons* (Fig. 48), but they are still lower in their organization than acrogens, for throughout their whole life they consist of cellular tissue only; and although some of them, as the *Mosses*, simulate the aspect of the higher orders of plants, by the appearance of a stem and roots, yet these organs never contain any woody fibres or vascular tissue, and their life consists in the imbibition of mineral matter by endosmosis; its elaboration within the cells by a process of digestion, which in the higher plants is assigned to special organs, or leaves; and in the reproduction of young cells by a process of internal generation, or fission, very inferior to that found in higher plants, where the function of reproduction is assigned to a special class of organs, called flowers.

The principal plants referred by botanists to the class of *thallogens* are *Mosses*, *Liverworts*, *Funguses*, *Seaweeds*, and *Lichens*; together with the still lower forms consisting of single cells, such as *Desmids* and *Diatoms*.

9. **The Leaf.**—Leaves do not grow at random upon the stem of a plant, but at regular intervals according to certain laws, the symmetry of which resembles that of the laws that govern the production of crystals, in the mineral kingdom. The law of the production of leaves is called *phyllotaxis* (*φυλλοτάξις*), and is of two kinds—*alternate* and *opposite*.

A. *Alternate Leaves*.—Leaves are said to be alternate, when one leaf only is formed at the same point of the growing stem, and the portion of the stem included between two successive leaves is called an *internode*; the point at which the leaf is produced being called the *node*, because, as has been already shown, a power of forming a bud and branch essentially exists in the stem, wherever a leaf is produced.

The simplest case of alternate leaves is that of *distichous* or two-rowed leaves; in this case the leaves are placed alternately on opposite sides of the stem, so as to form two vertical rows of leaves exactly opposite to each other. If we number the

leaves of such an arrangement in the order of their development, we shall find the two vertical rows to consist of—

First row, . 1st . . 3rd . . 5th . . 7th . &c.

Second row, . . 2nd . . 4th . . 6th . . 8th . &c.

The *distichous* arrangement occurs in all *Grasses*, and in many other endogens, and is sometimes found in exogens.

The next simplest case of alternate leaves is that called *tristichous*, which is characteristic of the *Sedges*, and some other endogens. In this arrangement the leaves are placed in three vertical rows, as follows:—

First row, 1st . 4th . 7th . 10th

Second row, 2nd . 5th . 8th . 11th

Third row, 3rd . 6th . 9th . 12th

This arrangement is shown satisfactorily in Fig. 67. The *distichous* and *tristichous* arrangements form the basis of the phyllotaxis of almost all alternate leaved plants in the following way. If we write down the vulgar fraction, whose *numerator* is the number of *spires* or revolutions round the growing stem made by the leaves, before a new leaf is produced vertically over the first leaf; and whose *denominator* is the number of *internodes* formed in the same time; we may represent the *distichous* and *tristichous* phyllotaxis thus—

Distichous Phyllotaxis, $\frac{1}{2}$

Tristichous Phyllotaxis, $\frac{1}{3}$

These fractions signify that in both cases the spiral line traced round the stem joining the leaves in the order of their production makes only one revolution before we arrive at a leaf placed vertically over

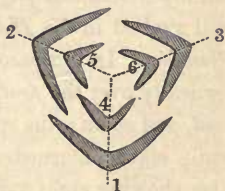


Fig. 67.

the first leaf; but that in the first case there are *two* internodes, while in the second case there are *three* internodes.

The arrangement next to be considered is the *dipentastichous*, found by adding the numerators and denominators of the preceding fractions together, thus—

Dipentastichous phyllotaxis, $\frac{2}{5}$

In this arrangement there are two revolutions of the spiral requisite to produce the leaf vertically over the first leaf, and there are five internodes produced in the two revolutions. It follows from this, that there are five vertical rows of leaves, which, however, are not generally well marked, because the length of the internodes, and the spiral lines generally draw off the eye from noticing the vertical ranks; which are,

First row,	1	6	11	16	21
Second row,	2	7	12	17	22
Third row,	3	8	13	18	23
Fourth row,	4	9	14	19	24
Fifth row,	5	10	15	20	25

The *dipentastichous* arrangement is illustrated in Fig. 68, and may be readily seen in the *Apple*, *Cherry*, or *Poplar*.

The next phyllotaxis of alternate leaves, in ascending order of complexity, is the *Trioctastichous*.

Trioctastichous phyllotaxis, $\frac{3}{8}$

This is found by adding together the numerators and denominators of the *tristichous* and *dipentastichous phyllotaxis*; and it may be well studied in the *Holly*, the *Aconite*, or the *Plantain*. In this case the *ninth* leaf is placed vertically over the *first*, the *tenth* over the *second*, and so on; the spiral making three turns while eight internodes are formed; and the stem showing eight vertical rows of leaves.

Other more complex forms are well known,

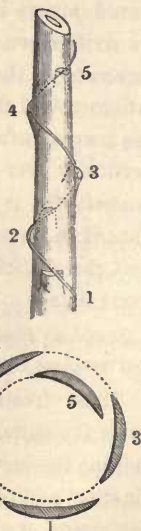


Fig. 68.

which are produced in like manner by the addition of the numerators and denominators of the fractions that represent the phyllotaxes; and the whole series is simply summed up in the following fractions, formed from each other, after the first two, by the same rule—

$$\frac{1}{2} - \frac{1}{3} - \frac{2}{5} - \frac{3}{8} - \frac{5}{13} - \frac{8}{21} - \frac{13}{34} - \frac{21}{55}$$

Here we may end the series, for higher combinations have seldom been found to occur in nature.

The *Houseleek* and *White pine* illustrate the phyllotaxis of $\frac{5}{13}$; and sometimes singular differences are found in the phyllotaxis of closely allied species. Thus the phyllotaxis of the American larch is $\frac{2}{5}$, while that of the European larch is $\frac{8}{21}$. The phyllotaxis of the white pine and black spruce is $\frac{5}{13}$, while other pines with thicker cones exhibit in different species the fractions $\frac{8}{21}$, $\frac{13}{34}$, and $\frac{21}{55}$; and not only do the phyllotaxes differ, but also the primitive direction of the primary spirals.

It is well known that the *turpentine*s formed by different pines differ in a similar manner, as to their rotatory power upon plane polarized light; and possibly these differences may be connected with differences in the phyllotaxis and spiral.

B. *Opposite Leaves*.—The simplest case of opposite leaves is that of two leaves produced always at the same node, and at opposite sides of the stem, the internode being in this case the interval between two successive pairs of leaves, instead of the interval between two successive leaves. When the opposite leaves that grow at the same node are more than two, they are called a whorl, and the leaves are said to be *whorled* or *verticillate*. It is generally found, whether the leaves be simply *opposite* or *whorled*, that each successive set of leaves occupies the spaces on the stem intermediate between the leaves of the last set, so that the stem presents *twice* as many vertical ranks of leaves as there are single leaves in any whorl. In this case, the *opposite* or *whorled* leaves are said to be *decussate*; but it sometimes happens, though very rarely, that the entire whorl follows a spiral order in the growth of the stem, each leaf of the whorl obeying some law of *phyllotaxis*.

axis, which is the same for all, and analogous to the spiral arrangement of alternate leaves already described.

The leaf grows from the stem, like the young plant from the seed, at first by the aid of two auxiliary leaves called *stipules*, which are somewhat analogous to the cotyledons of the young stem, Fig. 69 (*Quince*). Sometimes these are altogether absent, and in many cases they fade away as the leaf expands, like the cotyledons. Whenever stipules exist, they seem to be a provision for the growth of the young leaf which, like the young stem, requires a special organ for the digestion of its food in the earlier periods of its growth.

The other parts of the leaf are the leaf stalk, or *petiole*, and the blade, or *lamina*: the petiole is sometimes wanting, in which case the leaf is *sessile*, or has its blade resting immediately on the stem that bears it, and sometimes also there is no proper blade, but the whole leaf is cylindrical, or stalk-like. The leaf, in general, is to be regarded as a contrivance for increasing the green surface of the plant, so as to expose to the light and air the largest amount possible of cellular tissue, or parenchyma, containing the green matter of vegetation, or *chlorophyll*, upon which the light exerts its peculiar action in digesting the juice of the crude sap. The leaves are, therefore, to be regarded as expansions of the cellular tissue of the middle, or green bark, developed into a thin flat layer, and stiffened throughout by woody fibres, or veins, which are connected both with the woody fibres of the liber, or inner bark, and with the outer zone of the woody layers of the stem. These veins, formed by bundles of woody fibre, are distributed through the blade of the leaf in two diffe-



Fig. 69.

rent ways. They are either *reticulated*, as in Fig. 69, by successive subdivisions, or they run parallel to each other, as in Fig. 70 (*Eucharis*), with only a few transverse veins connecting the main branches, and are then called *nerved* leaves. As a general rule, to which, however, there are many exceptions, reticulated leaves are characteristic of exogens or dicotyledons, while nerved leaves are characteristic of endogens or monocotyledons.

The *venation* of the leaves is correlated with their general form and appearance, and names are given to leaves, of great importance in descriptive botany, which can be best understood by referring each form of leaf to the mode of distribution of its veins, or primary bundles of woody fibres.

The principal varieties of leaves are the following:—



Fig. 70.



Fig. 71.



Fig. 72.

(a.) The Needle-shaped leaf (*acicular*), Fig. 71 (*Pinus excelsa*). This is well shown in *Pines*.

- (b.) The *Palmate leaf*, Fig. 70 (*Horse chestnut*): both veins and leaf are said to be palmate, or like the fingers of the hand spread out.
- (c.) *Serrate or Dentate Leaf*, with *pinnate* nervation, Fig. 73 (*Oak*). There are many varieties of this leaf.
- (d.) *Pinnate Leaf*.—Fig. 74 (*Acacia*.)

The preceding are some few of the many varieties of leaves of the *reticulated* type. Of the *nerved* leaves there are two principal kinds, one shown in Fig. 70 (*Eucharis*) in which the nerves run parallel to the midrib, and the other shown in Fig. 75 (*Nile Lily*), in which the nerves or veins, parallel to each other, form two series of lines, making angles at each side of the midrib; both these sorts of nerved veins are commonly found in endogens, as in *Grasses*, the *Banana*, &c.

The essential function of the leaf is to elaborate the sap conveyed to it from the rootlets, by the ducts and vessels of the woody stem; and to transmit back



Fig. 73.



Fig. 74.



Fig. 75.

again into the stem, through the vessels of the liber, the digested, plastic sap, capable of depositing new cells and tissues. This function is exercised chiefly by evaporation, which in the case of many plants is effected upon a scale that is truly extraordinary.

The Rev. Dr. Hales found that a *Sunflower*, three and a half feet high, with a surface estimated at 5616 square inches, perspired at the rate of twenty to thirty oz. av. in twenty-four hours, or seventeen times more than a man. This loss of water, by evaporation, inspissates the juices of the leaf, and so causes, by endosmose, the ascent of the sap. It also causes the deposition of mineral salts in the cells of the leaf itself, and especially of its petiole, and so gradually tends to the death of the leaf—which is effected in exogens by a true *mortification* of the stalk, which drops off from the stem at the close of the autumn; and in the case of the endogens the same effect is produced by causing the gradual death of the leaf from above downwards, leaving the decayed stalks adherent to the stem, and withering around it, instead of being *amputated* as in the “fall of the leaf” of exogens.

“There is not wind enough to twirl
The one red leaf, the last of its clan,
That dances as often as dance it can,
Hanging so light and hanging so high,
On the topmost twig that looks up at the sky.”

Christabel.

10. **The Flower.**—The organs of the plant already considered are all devoted more or less to the great function of *nutrition*, which is essential to the continued existence of the individual. We have now to consider the structure of the *flower*, which is the organ specially devoted to the function of *reproduction*, which is essential to the continuance of the species. Flowers grow from buds, similar in form and structure to the leaf buds from which the branches are produced; and such buds as produce flowers are regarded by botanists merely as leaf buds, specially modified in order to fulfil certain functions. Leaf buds, as we have seen, are either terminal or axillary; and in like manner the flower buds are either terminal or axillary; giving origin to two distinct kinds of inflorescence, readily distinguishable from each other. These kinds of flowering are called *determinate* and *indeterminate*.

A. *Indeterminate inflorescence*.—In this case all the flowers are produced in the axils of the leaves of the growing branch, and the *inflorescence* is called *indeterminate*, because the flowers produced are indefinite in their number, which depends merely on the vigour with which the branch continues to grow, and to produce flowers from the axils of its leaves.

This form of inflorescence is represented in Fig. 76, which shows the whole flowering branch supported on a *common peduncle*, while each flower is supported on a *pedicel* or *partial peduncle*. When the flowers are *stalked*, as in the figure, the whole flowering peduncle is called the *axis of inflorescence*, and when the flowers are *sessile* it is called a *rhachis* (ράχις). Sometimes the flowers are produced on a flattened surface, instead of on a growing axis, and in this case the flattened surface is called the *receptacle*.

The *leaf bud* producing its branch and leaves, imitated the seedling in having stipules to represent the cotyledons; in like manner, the *flower bud* is frequently aided in its earlier growth by the nourishment supplied to it by one or more leaves developed upon the *partial peduncles*, which are called *bractlets*.

The term *Bract* is applied to the more or less modified leaf subtending the partial peduncle.

The following varieties of indeterminate inflorescence are universally recognized by botanists—

(a.) *Raceme* (*racemus*), (Fig. 76).—In this case, each flower, mounted on its own footstalk, is developed in its proper order of phyllotaxis, on the axis of inflorescence. The *Lily of the Valley*, and *Currant*, are good examples of the *raceme*. The raceme generally possesses both *bracts* and *bractlets*, but the latter are often so small as to escape notice. The lowest blossoms, being first developed, are the oldest, and the youngest blos-



Fig. 76.

soms occur nearest the tip of the axis; regarding, therefore, the extremity of the axis as a centre, the inflorescence is often said to be *centripetal*, and this character belongs universally to the indeterminate inflorescence caused by axillary flower buds.



Fig. 77.

- (b.) *The Corymb* (κόρυμβος), (Fig. 77).—This is the same as a raceme, in which the central axis is shortened and the lower pedicels lengthened, so as to bring all the flowers nearly to the same level; in the case of the corymb the term *centripetal* applied to the flowering becomes very appropriate: if we suppose the axis of the *Corymb* to be still further reduced in length, as often happens the growth from leaf buds, we shall obtain—

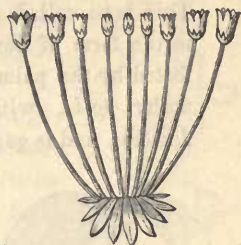


Fig. 78.

- (c.) *The Umbel* (umbella), Fig. 78.—This is a flower cluster, in which all the *pedicels* seem to spring from the same point, or top of the peduncle, so as to form a series of branching rays, resembling the ribs of an umbrella. These branching pedicels are called *rays*, and the united *bracts* are called an *involucre*. The *Corymb* may be well studied in the *Candytuft*, and the *Umbel* in the *Primrose*. The centripetal character of indeterminate inflorescence may be well seen in the *Umbel* and *Corymb*. In the preceding cases of inflorescence the flowers were all stalked; in the following they are *sessile*.

- (d.) *The Spike* (*spica*), Fig. 79, is a flower cluster, with a lengthened axis, and sessile flowers; and is a *raceme* without pedicels to its flowers. It is illustrated by the *Mullein*, *Plaintain*, and *Verbena*.



Fig. 79.

(e.) *The Head (capitulum)*, Fig. 80, is a round cluster of flowers, sessile, on a very short axis or receptacle; and may be regarded either as a *spike* with a very short axis, or as an *umbel*, with sessile flowers. A *head* may be either naked, or provided with an involucre formed by the bracts. The two following are merely special varieties of the *spike*.

(f.) *The Spadix (σπάδιξ)*, Fig. 81.

This is so called, because it is the form of flowering affected by the palm. It is a fleshy *spike*, with sessile, small, and often imperfect flowers; and is generally covered by a peculiar enveloping



Fig. 80.

leaf, called the *spathe* (σπάθη).

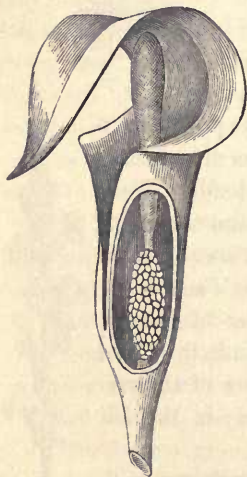


Fig. 81.

(g.) *The Catkin (amentum)*, Fig. 82, is a pendulous spike, with scaly bracts, and is well illustrated by the *Birch*. The *catkins* usually fall off in one piece, after flowering or fruiting. Trees that bear catkins are sometimes called *amentaceous*.



Fig. 82.

A series of *racemes* arranged in a racemose manner is called a *Compound Raceme*, which is well illustrated in Fig. 83.

(h.) *The Panicle (panicula)* Fig. 83. The term *panicle* strictly denotes a *compound raceme*, but is usually employed loosely by botanists to signify several kinds of compound or mixed inflorescence. It is a common form of inflorescence in *grasses*.

B. *Determinate inflorescence* occurs when the flower buds are *terminal*, and are produced, not in a single axis of inflorescence, but in a regular order of succession, one from the other, so that their total number may be predicted.

The *Cyme* (κῦμα) may be regarded as a general term denoting various kinds of determinate inflorescence; its flowering is said to be *centrifugal*, because the terminal flower buds are developed earlier than those farther removed from the central line. This is shown in Fig. 84, in which the central terminal flower appears in full blow, while the secondary flowers are less developed.

The following varieties of Cymes are recognized :—

(a.) *The dichotomous Cyme*, Fig. (85).

In this figure we observe the *primary* axis of inflorescence terminated by a flower, and producing in the axils of the bractlets of this flower two *secondary* axes, each of which in its turn produces a terminal flower, and a pair of *ternary* axes, which also produce terminal flowers; and *quaternary* axes, and so on. In



Fig. 83.



Fig. 84.

consequence of this continued and symmetrical subdivision, the inflorescence is said to be *dichotomous*.

- (b.) The *Uniparous Cyme*.—In this form of cyme the *primary* axis terminates in a single flower, which carries a single bractlet, from the axil of which is produced a *secondary* axis, which pushes aside the primary, and, like it, develops a terminal flower and *ternary* axis, and so on; hence we have produced the appearance of an *uniparous Cyme*, formed of a series of floral axes placed one above the other. There are two forms of uniparous cyme—one the *Scorpioid Cyme*, (Fig. 86), in which the flowers are arranged

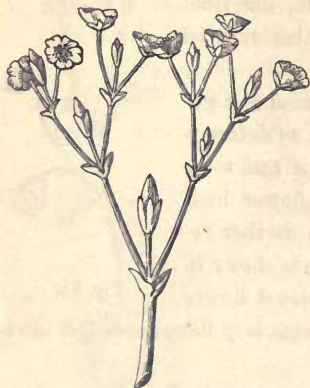


Fig. 85.



Fig. 86.

in two rows placed on the same side of the apparent axis, and the other, the *Helicoid Cyme*, in which the flowers are arranged in spiral order around the apparent axis. The *Scorpioid Cyme* may be well seen in the Borage Family; the *Helicoid Cyme* is much rarer, but may be studied in *Alströmeria*.

C. *Mixed inflorescence*.—There are frequently found forms of inflorescence combining the *definite* and *indefinite* varieties of inflorescence, which may be called *mixed inflorescence*.

Mixed Inflorescence may occur in one or other of two ways : either the primary divisions may be *indefinite*, and the ultimate subdivisions, *definite*, as is seen in the *Thyrus* (θύρσος), which may be regarded as a *Raceme of Scorpioid Cymes* ; or, on the other hand, the primary divisions may be *definite*, and the ultimate subdivisions indefinite, as is seen in many of the Composite Family, which often show *capitula* arranged in *Cymes*. As an example of the *Thyrus* we may mention the *Horse chestnut*.

The *Fascicle* (*fasciculus*), and *Glomerule* (*glomerula*), are varieties of Cymose inflorescence ; in the *fascicle*, the flowers are much crowded into a bundle, with a flattish termination ; and in the *glomerule*, the flowers are nearly sessile ; the *glomerule* may be distinguished from the *capitulum* by its centrifugal inflorescence.

D. *Organs of the Flower*.—In the most highly organized plants, the flower is composed of the following organs : *calyx*, *corolla*, *stamens*, *pistils* ; of these organs, the first two are regarded as accessory, and constitute the *perianth*, while the latter organs are essential to the reproduction of the plant, and constitute its male and female elements respectively. All of these organs are regarded by botanists as modified leaves, and they are arranged upon the flower stalk, according to the law of arrangement of whorled leaves ; that is, the *calyx*, *corolla*, *stamens*, and *pistils*, form four successive whorls, composed of a definite number of elements, and so placed in succession, that each whorl occupies the intervals of the whorl below it. The internodes between the successive whorls are usually suppressed, so that all the organs seem to spring together from the end of the flower axis. An ideal diagram of the four whorls, *calyx*, *corolla*, *stamens*, *pistils*, is shown in Fig. 87, where the suppressed internodes are supposed to be restored, and the floral whorls are shown separated from each other by intervals on the flowering axis.

The leaves composing the *Calyx* are called *sepals* ; and those

composing the *corolla* are called *petals*; they are commonly equal in number, and the flower is called *trimerous*, *tetramerous*, or *pentamerous*, according as these leaves are three, four, or five in number. In a perfectly regular flower, the *stamens* and *pistils* are each equal in number to the *sepals* and *petals*, and alternate in whorls with them, as is shown in Fig. 88, which represents the horizontal section of a perfect and regular *pentamerous* flower. In Fig. 89 is shown the horizontal section of a *trimerous* flower, in which the number of stamens is six, making five circles of flower organs instead of four; but the alternating succession of whorls remains as before, and the phyllotaxis of the flower is still that of whorled leaved plants.

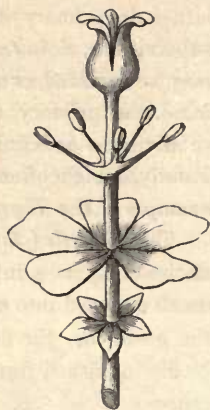


Fig. 87.

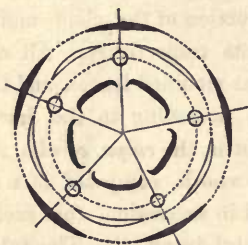


Fig. 88.

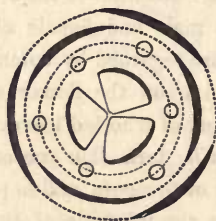


Fig. 89.

- (a.) *The Calyx* (κάλυξ).—This is the outer whorl forming the perianth of the flower, and is sometimes double, or may consist of a number of imbricated leaves, as in the *Cactus* family. There is no difficulty in regarding the sepals of the calyx as true leaves; and there is also little difficulty in showing that the whorled structure of the calyx arises from

the shortening of the axis of growth ; so as to condense into one whorl the complete *phyllotaxis* of the *alternate* leaves in the case of *trimerous* and *pentamerous* flowers ; and to condense into one whorl two successive sets of *opposite* leaves, in the case of *tetramerous* flowers.

In the case of *pentamerous* flowers, the calycinal whorl is formed by the condensation of the *phyllotaxis* of $\frac{2}{5}$; and this

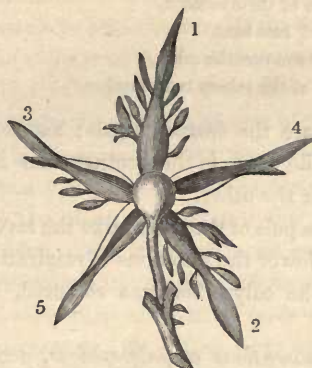


Fig. 90.



Fig. 91.

structure of the calyx is well shown in the case of the *Rose*, which has a *phyllotaxis* of $\frac{2}{5}$ ths, and in which the successive growth of the five leaves of the calyx may be recognized as following the usual law of the leaves of the entire plant. This is represented in Figs. 90 and 91 where it will be seen that the leaves from 1-5 have had time to develop themselves in proportion to the time of their formation, and so form a series of unequally developed sepals, quite different from those usually found in *pentamerous* flowers, in which the alternate *phyllotaxis* of $\frac{2}{5}$ ths has had time to be converted into the whorled structure of five leaves.

This curious peculiarity of the *sepals* of the rose has given rise to the monkish doggerel—

“Quinque sumus fratres,
 Sub eodem tempore nati,
 Bini barbati,
 Bini sine crine creati,
 Quintus habet barbam,
 Sed tantum dimidiatam.”

These lines have been rendered into English, thus—

“Five brothers there are,
 Born at once of their mother,
 Two bearded, two bare,
 One neither one nor the other,
 But of both of the others twin brother.”

The leaves one and two are the *bearded* sepals; and four and five are the *bare* sepals; while three is the brother that is *half-bearded*; or “neither one nor the other.”

Generally speaking, the sepals of the calyx, like the leaves, are green, and perform for the flower the functions of respiration and digestion, but occasionally the calyx becomes coloured, and is then called *petaloid*.

The calyx is either *monosepalous* or *polysepalous*, according as its sepals are united into one leafy tube, or remain as distinct leaves of the whorl. It is also *regular*, or *irregular*, according as the sepals composing it are equal and symmetrically placed, or are unequal, some being developed into *spurs*, *hoods*, and other forms, shown in the *Pelargonium*, *Monkshood*, &c.

(b.) *The Corolla* (*corolla* = *coronella*).—The corolla, like the *calyx*, is composed of leaves, which are called *petals*, and a corolla is called *polypetalous* or *monopetalous*, according as the parts are separate or united into one tube. The petals differ in general from the sepals, in being variously coloured instead of green; and they appear to perform digestive functions differing considerably from those of green leaves; for they frequently secrete honey in organs named *nectaries* at their base, and they seem, also, in

other ways destined to provide nutriment of a special kind for the growth and developement of the essential organs of the flower. The petals of the corolla present remarkable irregularities and appearances, assuming the form of various insects, and being often gaudily coloured, so as to attract the notice of insects, which visit the flowers to extract honey; and so get their probosces and legs covered with *pollen* from the anthers, which is then unconsciously carried by these insects to other flowers of the same kind, and deposited on the *stigmas* of their pistils, so as to fertilize the *ovules* of one plant by the *pollen* of another. There can be little doubt that the Final Cause of most of the beautiful flowers in nature is to please and attract the notice of insects, and so to make them subservient to the important function of reproduction of the plant, by carrying the pollen dust from flower to flower. The irregular forms assumed by the petals of plants are endless in number, and receive various names according to their shapes, such as *spoon-shaped*, *boat-shaped*, *saccate*, *spurred*, &c., &c. One large and highly important natural family (*Papilionaceæ*) derives its name from the resemblance of its flowers to the *Butterfly*; other plants, as the *Bee Orchis*, the *Fly Orchis*, &c., are so called from their flowers closely resembling the insects after which they are named.



Fig. 92. Some flowers, as in the *Compositæ*, Fig. 92, have *strap-shaped* petals; and a large natural family is called *Labiæ* (*Salvia*) Fig. 93, from the two-lipped appearance of its corolla; others are called *personate* from the supposed resemblance of the corolla to a mask, as in *Snapdragon*; and all the varieties of form in the petals of the corolla are used by botanists as specific characters, of great value, because they are so readily observed.



Fig. 93.

- (c.) *The Stamens*.—These form the third of the floral whorls, and are regarded as modified leaves, devoted to the special function of producing *pollen grains*, which constitute the male element in plants, and are necessary to the fertilization of the *ovules*. The stamen consists of two parts, Fig. 94, the *filament* or stem, and the *anther*, corresponding to the folded blade of a leaf, and containing the pollen grains. The passage from an ordinary leaf into a stamen is well shown in the *White Water Lily*, Fig. 95, which presents, in passing from the outer to the inner floral whorls, a complete gradation from green *sepals* on the outside to *petaloid sepals* inside, which again pass into true *petals*, which in turn become changed into *stamens*, acquiring at first traces of yellow anther, like tips, and becoming more and more like true stamens, until the change is completely effected, and the inner rows of the floral whorls appear provided with *filaments* and *anthers* as true *stamens*.



Fig. 94.

From the foregoing explanation, it will be readily understood, that the typical *anther* consists of two cavities, corresponding to the two halves of the original leaf, and which contain the *pollen grains*. When the pollen grains are fully ripe, the anther opens at each side, in various ways, which are highly characteristic of different families of plants, and form important means of distinguishing them from each other. The mode in which the anther is mounted on the filament also furnishes distinctions which are much used by systematic botanists. A very brief account of some of these peculiarities is all that can be inserted here.

The ring of stamens, like that of sepals and petals, may be more or less united together, a circumstance which gives rise to the following varieties:—

1. *Monadelphous* stamens, in which all the filaments are united together into a tube, at their bases; as in the *Mallow* and *Passion Flower*.

2. *Diadelphous* stamens have the filaments united into *two* sets, as in almost all the *Papilionaceous* flowers; in these flowers there are *nine* filaments united to form one set, and *three* filaments united to form the other.
3. *Triadelphous* stamens; filaments united into *three* sets, as in the *St. John's Wort*.
4. *Polyadelphous* stamens; filaments united into five or more sets at the base.



Fig. 95.



Fig. 96. Fig. 97. Fig. 98.

5. *Syngenesious* stamens are stamens united together into a ring or tube, by their anthers instead of by their filaments, as in the *Lobelia*, the *Violet*, and the *Composite* family.
6. *Innate* stamens are those in which the anther is attached to the filament, at its apex, as in Figs. 94, 95, and 98.
7. *Adnate* stamens are those in which the anther is attached by one face, usually for its whole length, to the side of the filament, Fig. 97.
8. *Versatile* stamens are those in which the anther is fixed by its middle to the very point of the filament, so as to swing loosely, as in the *Lily*, *Grasses*, &c., Fig. 96.

The final cause, or function of the anther, is to produce the *pollen*, which is the powder, or fine dust, that fills the cells of the anther, and is usually of a yellow colour, and is discharged when the anther is ripe, by the splitting up of the anther cells along their margin, or sometimes, as in *Rhododendron*, through circular

apertures at the summit of the anther cells. The *pollen* is found, under the microscope, or even lens, to consist of roundish grains, which differ from each other in form and appearance in different plants.

(d.) *The Pistils*.—The *pistil*, like the stamen, is a modified leaf,



Fig. 99.



Fig. 100.



Fig. 101.

but is formed in a different way. In the stamen, Fig. 99, the two halves of the leaf are rolled inwards so as to meet at the midrib and form *two* cells in the anthers, while the lower part of the leaf and its stalk are converted into the *filament*. In the *pistil*, however, Fig. 100, the edges of the leaf are rolled inwards, so as to meet each other, and form only one chamber, called the *ovary*, while the upper part of the leaf forms the *style*, terminated by the summit, devoid of epidermis, which is called the *stigma*. This transformation of the leaf into the pistil is beautifully seen in the *double cherry*, Fig. 101, in which, by a retrograde metamorphosis, the pistil is reconverted back into its original type of the leaf.

The final cause, or function, of the *pistil*, is to produce the

ovules, which grow, Fig. 100, from the united margins of the leaf, which are called the *placenta*, from a fanciful analogy borrowed from the Animal Kingdom. The *pistils*, taken together, form the fourth and last, or innermost of the floral whorls, and they may be united or separate from each other, like all the elements of the three preceding whorls. The different arrangements of the pistils, and of the ovules in their ovaries, constitute, as might be expected, some of the most important distinctions among plants.

1. *The simple pistil, or Carpel*, is found, when the several members of the whorl are distinct from each other, and is illustrated by Figs. 100, 101. It may be well studied in *Stonecrop*, which has five such carpels arranged distinct from each other, in a circle; each carpel having its ventral suture, or placenta, with ovules attached, turned towards the axis of the flower.
2. *The many-celled compound pistil* is formed by the union of the simple pistils of the whorl into one central mass, having as many chambers as there are carpels, with their placentas fused into a common central column, terminated by one stigma, or by stigmas equal in number to the pistils, according as the fusion of the members of the whorl has been more or less complete. This kind of pistil may be studied in the *Saxifrage*, and *St. John's Wort*.
3. *The one-celled compound pistil*.—In the many-celled compound pistils there was a central or axile placenta formed by the fusion of all the leaf margins, and the divisions of the cells were formed of the folded leaves, and were essentially double. These divisions are called *dissepiments*. When the dissepiments disappear, the pistil becomes one-celled, and has either a *free central placenta*, Fig. 103, or has *parietal placentas* equal in number to the number of pistils in the floral whorl, Fig. 104. The first of these arrangements requires no explanation, as it is an obvious consequence of

the fusion of the simple pistils by union at the central axis. The mode of formation of the one-celled pistil with parietal placentas is shown in Fig. 105, in which three leaves



Fig. 103.



Fig. 104.



Fig. 105.

forming three carpels of the floral whorl are supposed to be arrested in their progress by the apposition of the edges of the neighbouring leaves, so that each leaf, instead of being folded inwards on itself, and uniting its own opposite edges to form a *placenta* for the production of *ovules*, unites with the edge of a neighbour leaf of the same floral whorl, and forms, as is shown in the figure, a one-celled ovary, with parietal placentas, equal in number to the leaves that constitute the whorl.

4. *Naked ovules*.—There are three families of plants, the *Cycads*, *Conifers*, and *Gnetads*, in which there is no closed pistil formed by the infolding of the leaf upon itself, but an open carpellary leaf, in the form of a scale, bearing one, two, or more naked ovules upon the lower part of its upper surface, Fig. 106. The carpellary leaves or scales in these plants form a cone, whose phyllotaxis is that of the plant itself; and at



Fig. 106.

the time of blossoming, the pistil leaves of the fertile cone diverge, and the pollen shed by the barren or stamiferous cones falls directly upon the naked ovules. These plants are, therefore, called *Gymnospermous*, and are remarkable, among other reasons, for this—that they formed the earliest known vegetation of the higher order of plants, in the Carboniferous and Jurassic periods of the history of the globe.

The *ovules* produced by the various forms of pistils become *seeds*, when fertilized by the pollen produced by the anthers of the stamens of the same kind of plant as that which produced the ovules. The fertilization and growth of the ovule forms a subject too difficult and wide for an elementary treatise ; and it is sufficient for us to observe, that after its growth and maturation is complete, the seed is shed by the plant, and received into the ground, ready to recommence again the series of changes already described, by which the embryo shoots out its *radicle*, *cotyledons*, and *stem*, and begins again the endless succession of transformations, returning in cycles, which constitutes plant life.

11. **The Fruit.**—The fertilized ovary, increased in size, and variously modified, in some cases by the adhesion of surrounding parts, becomes the *fruit* of the plant, the several varieties of which are minutely described by botanical writers. The outer, middle, and inner portions of the *fruit* are designated by the terms, *exocarp*, *mesocarp*, and *endocarp*. The *pericarp*, which is the name of the whole envelope, is frequently some modification of the adnate calyx, or of the receptacle of the pistils. Thus, in the *apple*, the juicy part of the fruit is formed of the fleshy adnate *calyx*; and in the *strawberry*, the juicy portion of the fruit is formed of the enlarged *receptacle*, which carries on its surface the minute and seed-like ripened ovaries. The following, among the many varieties of fruits, are worthy of description :—

- (a.) *The Berry (Bacca)*; a closed fruit (*indehiscent*), fleshy or pulpy throughout; as the *Grape, Currant, Tomato*.
- (b.) *The Hesperidium*; this is a berry with a leathery rind, as the *Orange, Lemon*.
- (c.) *The Gourd*; is a berry with a hard rind, usually formed of three *carpels*, with revolute parietal placentas bearing the ovules; as the *Cucumber*.
- (d.) *The Pome (poma)*; is a fruit composed of several carpels of cartilaginous texture, more or less enclosed in a fleshy pericarp formed by an expansion of the receptacle, or of the calyx.
- (e.) *The Drupe, or stone fruit (drupa)*; is a one-celled, one or two-seeded, closed fruit, with the *endocarp* hard or bony, and the *exocarp* fleshy or pulpy; as the *Olive, Peach, Plum, Cherry*; the *Raspberry* and *Blackberry* are formed of a number of *drupels*, resembling cherries in structure, and all mounted upon an elongated receptacle.
- (f.) *The Achene*; is a one-seeded, dry, hard, seed-like fruit, popularly called a seed; it is evident that it is not a seed, but a true fruit, from the styles or stigmas carried by it, or from the scar left by their removal; frequently the tube of the calyx is incorporated with the ovary, in *achenes*, and gives rise to appendages variously named according to their shape—a *crown*, a *pappus* (woolly tuft, like the beard of a grandfather), or a *beak*.
- (g.) *The Utricle (utriculus)*; is an *achene*, with a thin, bladdery, loose pericarp.
- (h.) *The Cariopsis, or grain* (literally *shrimp-like*); has the seed completely filling the cell, and its coat firmly consolidated throughout with the thin pericarp, as in *Wheat, Indian corn, &c.*
- (i.) *The Nut*; is a hard, one-celled, one-seeded, closed fruit, like an *achene*, but larger, and produced originally from an ovary of two or more cells, with one or more ovules in each, all of

which, save one, have been aborted during the growth of the *nut*; as in the *Cocoa Nut*; *Chestnut*; *Beechnut*, *Oak*. The *nut* is often enclosed in a sort of involucre called a *cupule*, well illustrated in the acorn of the oak.

- (k.) The *Samara*; is a *nut* or *achene*, with a winged margin, as in *Birch*, *Elm*, *Ash*.
- (l.) The *Pod*; is an opened fruit (*dehiscent*), and may be either simple or compound.
- (m.) The *Follicle* (*folliculus*); is a *pod* formed of a single pistil, and dehiscent by the ventral suture only; as in *Larkspur*, *Columbine*. The opened pod of the ripe fruit bears a striking resemblance to the folded leaf, from which it was originally derived, Fig. 100.
- (n.) The *Legume* (*legumen*); is a *pod* formed from a single pistil, which dehisces by both the ventral and dorsal sutures, so dividing the fruit into two pieces, or *valves*; as in the *Pea*, *Bean*.
- (o.) The *Loment* (*lomentum*); is a *legume*, divided transversely into many one-seeded joints, which usually fall apart at maturity; as in *Cassia*.
- (p.) The *Capsule*; is the *pod*, or dehiscent fruit, of any compound pistil, and consists of two or more *carpels*, or simple pistils, united into one body. The capsule may split up when ripe, in various ways:—
 1. Along the lines of junction of its original carpels, which is called *septicidal dehiscence*.
 2. Along the dorsal sutures of the original carpels, which is called *loculicidal dehiscence*.
 3. Along an equatorial, horizontal line, cutting off the covering of the upper part of the compound carpels, like the lid of a circular snuff-box—*circumscissile dehiscence*—which gives rise to—

- (g.) The *Pyxidium*; which opens by a circular horizontal line, cutting off the upper part as a lid; as in the *Shepherd's weather-glass*, or *Pimpernel*.
- (r.) The *Siliqua* (*siliqua*); is a slender two-celled capsule, or pod, with two parietal placentas, and a false partition, from which the valves separate in splitting; as in the *Wallflower*.
- (s.) The *Silicle* (*silicula*); is a *Siliqua*, whose length is not greater than twice its breadth; as in *Shepherd's purse*.
- (t.) The *Cone* (*strobilus*); is a scaly multiple fruit, resulting from the ripening of some kind of *catkin*, Fig. 82; as in the *Hop*, *Pine*.
- (u.) The *Galbalus*; is a fleshy, closed cone, which at maturity puts on the appearance of a *berry*, as in the *Juniper*, *Taxodium*.

CLASSIFICATION OF FRUITS.

A. Fruits formed of one flower—

a. Containing one carpel (MONOCARPOUS).

- a. indehiscent, dry (*achene*).
- b. indehiscent, succulent (*drupe*).
- c. dehiscent (*legume*).

β. Containing several carpels, forming as many pistils (APOCARPOUS).

γ. Containing several carpels, forming a single pistil (SYNCARPOUS).

- a. indehiscent, dry (*nut*).
- b. indehiscent, succulent (*berry*).
- c. dehiscent (*capsule*).

B. Fruits formed of several flowers (ANTHOCARPOUS).

CHAPTER IV.

THE LIFE OF PLANTS.

IN the preceding Chapter I have described the organs of plants as they are observed on dissection and comparison with each other; and we have now to consider these organs in action, as they exist during life, when each organ exercises the function it is destined by the Creator to fulfil. The former branch of botany is sometimes called Vegetable *Anatomy*, and the present is called Vegetable *Physiology*. Both terms are borrowed from the study of animal life, and have the same meaning in the vegetable as in the animal kingdom. The vital functions of plants are, however, not only fewer in number, but are also simpler in their character than those of animals, and may be conveniently classified under the following heads:—

1. Circulation.
2. Respiration.
3. Nutrition.
4. Reproduction.

Plants enjoy a *circulation* and *respiration* of their own, quite distinct from those of animals and following their own laws; while their *nutrition* and *reproduction* bear to those of animals a much closer resemblance. A short account of each of these vital functions will be sufficient for an elementary treatise, and is necessary for the proper understanding of the *Vegetable Kingdom*.

1. Circulation of the Sap. It has been established by means of numerous and accurate experiments and observations, that the

rootlets of a plant imbibe water and salts dissolved in water from the soil, and that the moisture so imbibed is carried upwards through the various *ducts* of the woody fibres of the plant into the leaves; where it undergoes various changes due to respiration and digestion, and becomes *elaborated* or concocted sap, endowed with the power of forming new cells and tissues in the several parts of the plant to which it is redistributed through the *ducts* and vessels of the *liber*, or inner bark. The whole process of the ascent of the crude sap from the roots to the leaves, and the descent of the elaborated sap from the leaves to the growing tissues of the plant, is called the *circulation* of the sap. Naturalists have succeeded in giving an explanation, based on physical laws, of the *ascent* of the sap, but no satisfactory explanation has yet been given of the *descent* of the sap.

The following simple experiment, made by *Dutrochet*, to illustrate the force of *Endosmose*, explains the principle on which the ascent of the sap depends. If a membranous bag of either vegetable or animal material be tied to the end of a glass tube, Fig. 107, and be filled with a strong solution of sugar, or gum, it will be found, on plunging it into a vessel containing pure water, that a disturbance of the molecular equilibrium of the two fluids takes place, and that they endeavour to equalise their densities by establishing double currents in opposite directions, across the membrane that separates them; that is to say, that the pure water enters the bag, and the solution of sugar or gum leaves the bag; both currents traversing the intervening membrane—but with different forces and velocities, so as to produce a disturbance of the statical equilibrium that ought to exist between the fluids. The current passing from the rarer into the denser fluid is the strongest, and after a short time a difference



Fig. 107.

of level is observed between the fluids, which may be readily measured and made the subject of observation. The difference of level between the two fluids is found to increase, until they both acquire the same density, when the force of *Endosmose* ceases, and the fluids, becoming subject to the usual laws of Hydrostatics, rapidly recover the same level.

While the difference in density of the two solutions continues, a very considerable difference of level may become established. Thus, when we use a solution of one part of sugar, to two parts of water, it is found that the difference of level, at the end of two days, may become equivalent to forty-five feet, when the solution is found to contain one part of sugar to three parts of water.

The force of *endosmose*, established numerically by experiment, is abundantly sufficient to explain the *ascent* of the sap. When the returning heat of spring inspissates the juices of the surface of the plant, and especially of its leaf buds, the force of *endosmose* draws up into those organs the less dense juices of the lower cells and vessels, and so acts from above downwards, till it reaches the extremities of the rootlets of the plant, which are in contact, either with pure moisture, or with very dilute solutions of organic and mineral salts, calculated to supply food to the plant.

During the summer, the evaporation of moisture through the stomates of the leaves keeps up the force of the *endosmose*, and prevents the fluids of the plant from attaining that equilibrium of density which would destroy the ascensional force, and restore them to the action of the ordinary laws of gravity.

In the autumn, however, the diminished evaporation gradually extinguishes the force of *endosmose*, and at the approach of winter the plant is abandoned to the influence of the usual laws of hydrostatics; its circulation slowly ceases, and it falls into the profound sleep that characterizes the plant life of the winter months; and which suggests to the thoughtful observer many points of analogy with the anæmic torpidity and retarded circu-

lation of the old age of man himself, from which there seems to be no springtime of rallying at this side the grave! An occasional warm day in winter, like a bottle of generous wine given to an old man, may rouse the latent circulation of the plant for a time, but the icy grip of winter again asserts its power, and the collapse is, for the time, final.

The force of *Endosmose* is unquestionably the great motive force that acts to cause the imbibition of fluids by the rootlets, and the ascent of the sap; and the origin of this force is the evaporation of moisture by the leaves. The variation in evaporation during the months of spring and summer is regulated by the declination of the sun, and in a secondary manner, by the character of the season.

The following results, obtained by Lawes and Gilbert, show the daily evaporation of pots of *wheat* and *peas* grown in unmanured soil:—

	<i>Wheat.</i>	<i>Peas.</i>
I. March 19 to March 28 (9 days), . . .	14.3 grs. . .	11.2 grs.
II. March 28 to April 28 (31 days), . . .	40.9 „ . .	42.9 „
III. April 28 to May 25 (27 days), . . .	162.4 „ . .	106.4 „
IV. May 25 to June 28 (34 days), . . .	1177.4 „ . .	1079.8 „
V. June 28 to July 28 (30 days), . . .	1535.3 „ . .	2092.7 „
VI. July 28 to August 11 (14 days), . . .	1101.4 „ . .	377.2 „
VII. August 11 to September 7 (27 days),	230.9 „ . .	— „

The total quantity of water given off by the *wheat* in the 172 days was 113527 grains, and by the *peas*, 109082 grains; and the mineral derived from the wheat was 36.49 grains, and from the peas 43.16 grains; showing that the *wheat* absorbed 32.14 grains of mineral salts, and the *peas* 39.59 grains for every 100000 grains evaporated by their leaves.

The force of *Endosmose* is fully sufficient to account for the *absorbing* power of the rootlets of plants, and for the ascent of their sap; and it also serves to account for the selecting power now generally attributed to the rootlets; for the endosmotic force varies, not only with the density of the two fluids separated by

an organic membrane, but with the nature of the fluids themselves and of the membrane. Thus, the careful experiments of physicians have proved that the relative motions of fluids, under the influence of endosmose, depends upon their *specific heat*; so that *the fluid possessed of the greatest coefficient of specific heat always moves towards the fluid possessed of a lesser coefficient*; from this it follows that pure water (which has the greatest specific heat of all fluids) must move towards any other fluid; and in the endosmotic action, solutions of salts, having a high specific heat, will readily pass through the membrane, while those possessing a low specific heat will be left behind.

The natural food of plants consists chiefly of *water*, *carbonic acid*, and *ammonia*—together with small quantities of mineral salts, varying with the kind of plant.

The natural excretions of the animal kingdom consist of *water*, *carbonic acid*, and *urea*, which is rapidly converted into *carbonate of ammonia*—together with some mineral salts, in general similar to those used in the food of plants, such as phosphates and other salts of magnesia, soda, potash, &c.

These two kingdoms of nature thus compensate each other's action, the excretions of one forming the food of the other, and *vice versa*. The carbonic acid excreted by the lungs of animals, and produced by the combustion of coal and wood, becomes a constituent part of the air we breathe, and would destroy animal life if it attained to four per cent. of that air; but, by the wonderful compensation of the vegetable kingdom, it is absorbed by the leaves of plants in respiration, and resolved into carbon and oxygen; the former of which becomes fixed in the woody fibres of the plant, while the oxygen is given back to the atmosphere, and renders it again fit for the respiration of animals.

The *urea* excreted by the kidneys of animals is rapidly converted into carbonic acid and ammonia, both of which are dissolved by moisture, and conveyed to the roots of plants, whence they are pumped up by *endosmotic* force into the leaves.

The food of plants may therefore be thus classified, according to its composition and mode of reception :—

- | | | |
|---------------------------|--|--|
| i. Nitrogenous food, . | { Ammonia,
Nitrates, . } | —by endosmose. |
| ii. Non-Nitrogenous food, | { Water, . .
Carbonic Acid, } | —by endosmose.
—by respiration,
partly by endosmose. |
| iii. Mineral Salts, . . | { Phosphates,
Chlorides,
Bromides,
Iodides,
Fluorides,
Silicides, } | —by endosmose. |

The sap brought from the roots, in its passage up the stem, is variously modified by dissolving other substances in the cells it passes through, and ultimately reaches the leaves, where it undergoes still greater changes, by being brought under the influence of the function of respiration, which must be now described.

2. Respiration of Plants.—The respiration of plants is the inverse of the process called the respiration of animals. It is well known that animals of the higher orders inspire and expire air by means of their lungs, which are the organs proper to respiration; the inspiration and expiration depending on the movements of the intercostal muscles, which connect the ribs that enclose the cavity of the chest containing the lungs. In animals, the inspired air is deprived of a portion of its oxygen, which is replaced by carbonic acid in the expired air; but in plants, the process of respiration, although not performed by alternate inspirations and expirations, is the inverse of the preceding, and consists in the absorption of carbonic acid by the leaves, and its replacement by the exhalation of oxygen through the *stomates* of the same organs. Atmospheric air is composed of seventy-nine parts of nitrogen to twenty-one of oxygen, with a minute quantity of carbonic acid; and it is the latter gas that furnishes the proper

source of the special respiration of plants. This fact is established by the following observations :—

1. If a plant be allowed to grow in a glass bell filled with air that is permitted to remain unchanged for a certain time, and this air be analyzed from time to time ; it will be found to have lost carbonic acid and to have gained oxygen.
2. A plant produced from a seed may be allowed to vegetate in pure sand watered with distilled water, so as to preclude the possibility of any food, other than water, reaching it except by *respiration* from the air. If, after a certain period of growth, the plant be analyzed, and compared with the analysis of other seeds similar to that which produced it, the result of the analysis is always found to be, that the plant gains *carbon*, which must have been derived directly from the air, which contains this substance only in the form of carbonic acid ; and hence we infer, as in the former case, that growing plants have the property of decomposing carbonic acid by their leaves, and of giving back to the atmosphere the oxygen disengaged by the process of decomposing the carbonic acid. It has been repeatedly proved that the decomposition of carbonic acid, which is called the *respiration* of the plant, is effected by the agency of the *green* cells, containing *chlorophyll*, and that sunlight is necessary to the perfection of this function. When plants are excluded from the influence of the sun's light, their green parts become blanched, and they cease to respire ; that is, they cease to convert the carbonic acid of the air into carbon and oxygen ; so that the respiration of plants is not a function, like that of respiration in animals, necessary to their existence ; but is a function whose activity requires a special stimulus, like that of sunlight, for its manifestation. When an animal ceases to breathe, it dies ; and in the highest animals, such as man, a cessation of breathing for sixty-five seconds is sufficient to cause death ; in plants, however, the cessation of respiration causes a change

of colour only, but not a cessation of growth, much less of life itself. Under such circumstances, however, plants suffer much, although not so much as animals; they never acquire proper developement, no green colour appears in their stems or leaves, little or no woody fibres are formed in their tissues, and their whole energy is expended in the production of weak watery shoots; and, finally, they cannot continue to live under such circumstances, unless supplied with *organic* nutriment; for they have been deprived of the sunlight, and sun-heat, which are the natural forces that enable the plant to convert *mineral* into *organic* products.

This remarkable process, called the *respiration* of plants, might more justly be described as a *deoxydating* process, which the green leaves and cells of plants are capable of effecting under the stimulus of sunlight. It bears no analogy whatever to the respiration of animals, which consists simply of the excretion of carbonic acid, produced by the oxydation or combustion of the animal tissues, and which is accompanied, as everybody knows, with the liberation of heat, that measures exactly the force consumed in the combustion. In the *respiration*, or rather *deoxydation*, effected by plants under the influence of sunlight, on the contrary, we have exhibited the reverse process of the *storing up*, instead of the *expenditure* of force, by the action of vital agencies, and this action is accompanied by the production of cold, instead of heat, and also by the conversion of lower forms of chemical compounds into higher forms.

The following list of non-nitrogenous vegetable products shows how intimately they are related to *carbon* and *water*, although it is not to be supposed that they are simply formed of these substances:—

1. Cellulose, . . .	12 atoms of carbon + 10½ atoms of water.
2. Starch, . . .	12 " + 10 "
3. Dextrine, . . .	12 " + 10 "
4. Grape Sugar, .	12 " + 14 "
5. Cane Sugar, .	12 " + 11 "

Chemists are not agreed as to the mode in which carbon becomes fixed by plants; but the views of Draper are more generally received than other theories on this subject. Mr. Draper considers that the nitrogenous elements brought up from the roots into the leaves perform the part of a *ferment*, and excite what is called *contact action* upon the carbonic acid introduced through the stomates of the leaves, and so produce the fixation of carbon, and the liberation of oxygen from the green cells; and even though we cannot understand the precise mode of operation, we can readily conceive the extreme importance of this remarkable process, which ought to be called a *secretion of carbon*, rather than a *respiration* of the plant.

3. **Nutrition of Plants.**—The chief food of plants, as already stated, consists of *ammonia*, *carbonic acid*, and *water*; of which the ammonia and water are supplied principally by the roots, and the carbonic acid by the atmosphere, to the leaves. The absorption of carbonic acid and its deoxydation by the green cells are effected only under the influence of sunlight; while, during the night, and always when the plant is grown in total darkness, an *inverse* process goes on, analogous to that which maintains the life of animals, and which consists chiefly of the oxydation of carbon into carbonic acid by the absorption of oxygen from the air. In fact, when a plant is grown under a bell glass, and is found to give out oxygen, and absorb carbonic acid, this result is really not a simple action of the plant, but is the difference of two distinct and opposite actions—one of *respiration* (so called), by which carbonic acid is absorbed and oxygen set free; and the other, of *digestion* or *nutrition*, by which oxygen is absorbed and carbonic acid set free. This process of *nutrition* seems to be constant, and to be necessary to the continued life of the plant, as it is well known to be to the continued life of the animal; while the process of *respiration* varies with the degree of exposure of the plant to sunlight, and is a function, like that of muscular exercise in the animal, necessary rather to the health of the being

than to its bare existence. Very little is as yet known of the inner chemistry of this function of *nutrition*, and still less of its relations to the more active function of *respiration*. Judging by the excess of the products of respiration in healthy plants, over the products of the excretions produced by nutrition, we are entitled to say, that the plant *gains*, instead of *losing* force, during the whole period of its existence, and terminates a useful career, like a miser, by storing up organic products, which afterwards serve for the nutrition of various forms of animal life, such as the *Herbivores*, which in their turn store up nitrogenous food for the nourishment of still higher forms of existence, such as dogs and men. "Happy," says a French proverb, "are the children of the damned," for they enjoy without scruple the savings of avarice and crime. The innocent plants produce and yield up their stores to others without any drawback.

The excretions and secretions formed by plants are the joint product of all the chemical reactions caused both by *respiration* and *digestion*; and some of the most important of them have been already mentioned. Their composition, in atoms, is as follows:—

	C.	H.	O.
I. Starch,	12	10	10
II. Dextrine,	12	10	10
III. Cellulose,	12	10½	10½
IV. Gum,	12	11	11
V. Cane Sugar,	12	11	11
VI. Fruit Sugar,	12	12	12
VII. Starch Sugar,	12	14	14
VIII. Mannite,	12	14	12
IX. Oxalic Acid,	2	0	3
X. Malic Acid,	8	4	8
XI. Citric Acid,	12	5	11
XII. Tartaric Acid,	8	4	10
XIII. Tannic Acid,	18	5	9

The volatile oils excreted by plants are very numerous, and are usually secreted in glands, either external or internal, situ-

ated in the herbaceous parts of plants. They are seldom pure, but contain dissolved resinous matters, camphor, and active principles of various kinds.

Resinous and waxy secretions are very varied, both as to mode of occurrence and composition; they are found on the surface of the leaves and fruits, and on the outer coat of the pollen of many plants.

The milky juices of plants (*latex*) contain essential oils, gum resins, starch grains, and alkaloids, suspended in water, and forming a kind of emulsion. These juices are found especially in certain natural orders of plants, and are frequently of great commercial importance—as, for example, *opium*, *caoutchouc*, and *gutta percha*.

The *alkaloids* form an important group of vegetable products, many of which are poisonous, and which agree with each other in containing nitrogen. They are much used in medicine, especially of late years, and are highly esteemed; among the most important may be mentioned—

	C.	H.	N.	O.
I. <i>Conia</i> ,	10	15	1	0
II. <i>Nicotina</i> ,	10	7	1	0
III. <i>Cinchona</i> ,	40	24	2	2
IV. <i>Quinia</i> ,	40	30	2	10
V. <i>Morphia</i> ,	34	19	1	6
VI. <i>Narcotina</i> ,	46	25	1	14
VII. <i>Strychnia</i> ,	42	22	2	4
VIII. <i>Brucia</i> ,	46	26	2	8
IX. <i>Caffeina</i> ,	16	10	4	4

Conia is the alkaloid that gives to *Hemlock* (*Conium maculatum*) its celebrated poisonous properties; it pervades the whole plant, but is most easily obtained from the seeds.

Nicotina agrees with *Conia* in being destitute of oxygen; it forms the poisonous principle of *tobacco* (*Nicotiana tabacum*), and occurs in that plant in combination with *malic* and *citric* acids.

Cinchona and *Quinia* are valuable alkaloids, found in the several varieties of pale, yellow, and red Peruvian *barks*. These valuable remedies for ague were first made known by the Jesuit missionaries in South America, and active exertions are now being made to naturalize the *cinchona* plants in Hindostan.

Morphia and *Narcotina* are two of the alkaloids occurring in the *Poppy*, and forming essential parts of crude *opium*; *Morphia* constitutes the chief active ingredient in this drug, and is a well known powerful narcotic poison; *Narcotina* forms an ingredient of opium almost as important as *Morphia*, and, like this alkaloid, is a powerful narcotic poison, only less active.

Strychnia and *Brucia* are alkaloids occurring in the St. Ignatius bean (*Strychnos nux vomica*), and both act as powerful poisons, producing symptoms the opposite of those caused by *Nicotina*, but equally fatal. These poisons have been successfully used as antidotes (physiological) to each other.

Caffeine, or *Theine*, is the alkaloid present in the tea and coffee plants, and in other plants similar to them in properties, such as the Maté or Paraguay tea plant. This valuable alkaloid forms a portion of the daily food of three-fourths of the human race, and exerts important physiological effects of a most beneficial kind, which cannot be here further considered. Like most stimulants, when used in excess, it produces loss of sleep, nervous excitement, and symptoms of congestion of the brain.

From the foregoing statement it will be seen that the secretions formed by plants, under the joint influence of the *absorption* of nitrogenous food by the roots, and of *carbonic acid* by the leaves, are very varied, and but little known. They consist of nitrogenous and non-nitrogenous products, which have been studied by the chemists, but whose secretion and distribution in the plant that forms them are almost wholly unknown to the botanist.

4. Reproduction of Plants.—Plants are reproduced either by subdivision, natural or artificial, or by the formation of seeds,

which reproduce the image of the original plant in its integrity. The first kind of reproduction of plants is sometimes called *vegetative multiplication*, in order to distinguish it from true *reproduction*, and is not without numerous analogies in the animal kingdom also.

A. *Vegetative Multiplication*.—One of the most remarkable examples of vegetative multiplication is to be found in the history of the *Weeping willow* (*Salix Babylonica*), which is a native of Mesopotamia, and immortalized in the most beautiful of all the Hebrew Psalms, cxxxvii.

By the rivers of Babylon we sat down ;
And wept, when we remembered thee, Zion.

We hanged up our harps
On the Willow trees of the streams.

They that made us captives asked for a song ;
Our spoilers asked us for mirth.

Sing to us, Oh sing to us, the songs of Zion ;
How shall we sing ; how shall we sing !
The song of Jehovah in the land of the stranger ?

In the reign of Queen Anne, the poet Pope was staying with the Countess of Suffolk, when she received a parcel from Spain, bound with withes, which seemed yet alive ; Pope took one of them and planted it in his garden at Twickenham, where it became celebrated as Pope's Willow. It was originally introduced by the botanist Tournefort into Europe, and since its introduction it has been propagated by cuttings only and not by seeds, so that every weeping willow in Europe is literally part of the same tree, that possibly still grows on the banks of the Euphrates. The foregoing is a remarkable occasional instance of *vegetative multiplication* in the case of one of the higher plants ; but in the lower forms of plants this is the mode of reproduction that usually occurs, and by which the plant is propagated.

In the group of plants called *Thallophytes*, where the entire organization consists of cells, and there is no leaf structure of any kind, the buds (*gemmae*) are congeries of cells, formed by division of original cells, and ultimately separated from the parent plant by a process of spontaneous *fission*, similar to that observed in the lower forms of animal life, such as *sponges* and *polyps*. This process of multiplication in the *Thallophytes* is strictly analogous to the vegetative multiplication of the higher plants by means of buds; but it is remarkable that in many *Thallophytes*, perhaps in all, there is a periodical formation of true reproductive cells, male and female, analogous to flowering, the union of which produces cells capable of commencing a new growth, and of reproducing the original plant in a manner strictly analogous to the formation of seeds, by the fertilization of the *ovules* by the *pollen*.

In the flowering plants, the principle of vegetative multiplication is exemplified in the leaf buds already described, which are capable, either naturally or by artificial means, of being developed into new plants, of the same kind as that which produced them. Thus the bulbiferous *Lily* is multiplied by means of axillary leaf buds that are spontaneously detached from the parent plant, and similar productive buds are often produced, instead of flowers, by the several species of *Garlic*, in which such buds are called *cloves*, and are highly prized, on account of the concentrated oils which they usually contain. In the *Potato*, the tuber is formed from the branch of the stem, and produces buds called "eyes," which are separable from the parent stem, and capable of producing each a new plant. A similar condition prevails in the *Jerusalem Artichoke*, *Dahlia*, and other well known cultivated plants.

The leafy shoots, called *runners* in the *Strawberry*, and called *offsets* in the *Houseleek*, are simply modifications of axillary buds, and are examples of the mode in which the vegetative multiplication of plants is variously effected, by a principle that seems to pervade the whole vegetable kingdom,

from its lowest members to the highest, and which passes beyond that kingdom, into the lower regions of the animal kingdom. Gardeners take advantage of this principle in the several operations described as forming *slips*, *cuttings*, *layers*; and also in *budding* and *grafting*; all of which consist in detaching either buds, or shoots proceeding from buds, from the parent plant, and causing them to grow, either directly in the ground, or in the *cambium* layer of some other plant.

B. *True Reproduction*.—It was at one time thought by botanists that the two great subdivisions of the Vegetable Kingdom; viz., *phanerogams* and *cryptogams*, might be distinguished from each other as being propagated, one by a true reproduction, and the other by vegetative multiplication; but it is now generally recognized that both classes of plants are actually reproduced by both processes.

(a.) *Flowering plants*.—The production of seeds depends on the fertilization of the *ovule* by the *pollen*; the ovule is produced by the *pistil*, and the pollen is produced by the *stamen*; when both are fully ripe, the pollen is scattered by the wind, or carried accidentally by an insect, and reaches the *stigma* of the pistil, which is destitute of epidermis; the *pollen*, as it were, takes root in the stigma, and a long slender filament grows down from it, until it reaches the ovule, Fig. 108, which at once begins to grow, and enlarges until it becomes the *seed*, provided with its *radicle*, its *plumule*, and *cotyledons*, already described; and at the same time the surrounding structures partaking of



Fig. 108.

the general stimulation and growth, form around the seeds the various kinds of fruits mentioned before, as *drupes*, *achenes*, &c.

(b.) *Flowerless Plants*.—There are various modes of true reproduction, as distinguished from vegetative multiplication, recognized in the flowerless plants, or cryptogams, all, however, reducible to the following:—

In the higher cryptogams the female organs are termed *archegonia*, the male *antheridia*. Within the latter are formed peculiar ciliated bodies, the *antherozoids*, which, entering the neck of the archegonium, reach its central cell, and thus the act of fertilization is effected.

In the lower cryptogams the female organs essentially correspond to the contents of the archegonia among the higher. Their fecundation is, in like manner, effected by contact with antherozoids. Such a mode of reproduction has been observed in several Algæ. The true reproduction of the Lichens and Fungi is still very imperfectly understood.

Some of the lower Algæ are reproduced by a simple process termed *conjugation*, or the union of two slightly dissimilar cells, supposed to represent the germ-cells and sperm-cells of higher plants.

Flowerless plants are also propagated by means of *spores* (*σπόρος*), minute bodies capable of germination, but differing alike from the seeds and free buds of flowering plants.

CHAPTER V.

THE CLASSIFICATION OF PLANTS.

THE classification of plants, like that of animals, depends upon the assumption that each *species* is distinct from all others, and reproduces itself, and not another species. It is assumed also by some naturalists that each species has a determinate time and place of origin, or creation, and that two origins, either in time or place, for the same species is an hypothesis not to be admitted. The *species* that resemble each other in some points, but are not produced by each other, are grouped in the same *genus*; but it is universally agreed that the *species* are entities, while the *genera* are more or less artificial, and the inventions of the mind itself that compares and examines them. Thus, while all botanists are agreed, or nearly so, as to the entity of *species*, it is admitted that difference of opinion may exist as to the *genera*, and much more so as to the larger groups into which plants may be divided. These larger groups are generally thus divided—

- I. *Individuals form Species* ;
- II. *Species form Genera* ;
- III. *Genera form Families, or Orders* ;
- IV. *Orders form Classes* ;
- V. *Classes form a Kingdom*.

When a plant is named by a botanist, it has been customary, from the time of Linnæus, to define it by naming the *genus* and *species* to which it belongs. Thus, the plant called *Conium maculatum* belongs to the genus *conium* (hemlock), and to the species with *spotted leaves* (*maculatum*). The generic name is placed first,

and the specific name last, the latter being always an adjective, or the genitive of a noun, with an adjective value.

The species being the only entity, it is a matter of comparatively little importance how they are grouped into genera and families; and therefore, many classifications have been proposed, some called artificial, and some called natural. The most famous and most perfect of the artificial classifications is that invented by Linnæus, which is still in use, and may be regarded as an artificial key to the names of plants.

1. **Classification of Linnæus.**—The object of the classification of plants by Linnæus was to form *classes* and *orders*, founded on characters of the plant easily observed; after which the *genera* were founded on other characters, differing in each case. Linnæus sought in the essential organs of the flower, viz., *stamens* and *pistils*, for the marks of distinction of his classes and orders.

The *Classes* of the Linnæan System are founded on the conditions of the *Stamens*.

The *Orders* are founded, either on the conditions of the *Pistils*, or on *secondary* characters of the *Stamens*.

The *Genera* are formed immediately under the Orders, being sometimes grouped together for convenience, into *Sub Orders*; but the groups of genera known to modern botanists as Families are, except in a few instances, ignored by the great founder of modern Botany.

There is a remarkable passage in the *Systema Naturæ*, which shows that Linnæus believed that the Almighty himself formed the *Natural Orders* of plants, and directed their subdivision into *Genera*; and that *Nature* afterwards, by a sort of tentative process, subdivided these *Genera* into *Species*, being again and again stopped in her attempts to make new species at random by the sterility of the hybrids she produced.

Buffon has eloquently stated, in his great work, similar views

with respect to the Classification of Mammals; and it seems to me that the doctrines of Linnæus and Buffon, as to the formation of species by a process of degeneration from original types, are as well worthy of our notice as the theory of Lamarck and Darwin, which obtains more favour in the present day, because it dispenses with the necessity of the hypothesis of a Creator.

The *Classes* formed by Linnæus, on the conditions of the stamens, are the following, in which a perfect flower signifies one with both stamens and pistils :—

	LINNÆAN CLASSES.	EXAMPLE.
I.	MONANDRIA, . . 1 free stamen; flower perfect, . .	<i>Centranthus.</i>
II.	DIANDRIA, . . 2 free stamens; flower perfect, . .	<i>Veronica.</i>
III.	TRIANDRIA, . . 3 free stamens; flower perfect, . .	<i>Crocus.</i>
IV.	TETRANDRIA, . . 4 free stamens; flower perfect, . .	<i>Galium.</i>
V.	PENTANDRIA, . . 5 free stamens; flower perfect, . .	<i>Campanula.</i>
VI.	HEXANDRIA, . . 6 free stamens; flower perfect, . .	<i>Tulipa.</i>
VII.	HEPTANDRIA, . . 7 free stamens; flower perfect, . .	<i>Æsculus.</i>
VIII.	OCTANDRIA, . . 8 free stamens; flower perfect, . .	<i>Erica.</i>
IX.	ENNEANDRIA, . . 9 free stamens; flower perfect, . .	<i>Rheum.</i>
X.	DECANDRIA, . . 10 free stamens; flower perfect, . .	<i>Saxifraga.</i>
XI.	DODECANDRIA, . . 12-19 free stamens; flower perfect, . .	<i>Reseda.</i>
XII.	ICOSANDRIA, . . 20 or more free stamens, inserted on calyx; flower perfect,	<i>Rosa.</i>
XIII.	POLYANDRIA, . . 20 or more free stamens, inserted on receptacle; flower perfect,	<i>Ranunculus.</i>
XIV.	DIDYNAMIA, . . 2 long, and 2 short, free stamens; flower perfect,	<i>Lamium.</i>
XV.	TETRADYNAMIA, . . 4 long, and 2 short free stamens; flower perfect,	<i>Cheiranthus.</i>
XVI.	MONADELPHIA, . . Stamens coherent into a tube or bundle; flower perfect,	<i>Malva.</i>
XVII.	DIADELPHIA, . . Stamens coherent into <i>two</i> bundles; flower perfect,	<i>Lathyrus.</i>
XVIII.	POLYADELPHIA, . . Stamens coherent into <i>three</i> or more bundles; flower perfect,	<i>Hypericum.</i>
XIX.	SYNGENESIA, . . Anthers coherent; inflorescence ca- pitulate,	<i>Bellis.</i>

Classes XVI. to XVIII. MONADELPHIA to POLYADELPHIA.	I. <i>Pentandria</i> , . . .	5 stamens.
	II. <i>Hexandria</i> , . . .	6 stamens.
	III. <i>Heptandria</i> , . . .	7 stamens.
	IV. <i>Octandria</i> , . . .	8 stamens.
	V. <i>Decandria</i> , . . .	10 stamens.
	VI. <i>Dodecandria</i> , . . .	12-19 stamens.
	VII. <i>Icosandria</i> , . . .	20 or more stamens on calyx.
	VIII. <i>Polyandria</i> , . . .	20 or more stamens on the receptacle.

Class XIX. SYNGENESIA.	I. <i>Polygamia æqualis</i> ,	All the florets perfect, and of the same shape.
	II. <i>Polygamia superflua</i> ,	Capitules radiate; disk florets perfect; ray florets pistillate; all forming seeds.
	III. <i>Polygamia frutanea</i> ,	As the last, except that the ray florets are neutral.
	IV. <i>Polygamia necessaria</i> ,	Ray florets pistillate; disk florets staminate.
	V. <i>Polygamia segregata</i> ,	Ray florets perfect; each floret having an additional calyx or involucl.

Classes XX. to XXIII. GYNANDRIA to POLYGAMIA.	<i>Monandria to Polyandria.</i> <i>Monadelphica to Polyadelphica.</i>
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CLASS XXIV. CRYPTOGAMIA.	I. <i>Ferns.</i> II. <i>Mosses.</i> III. <i>Seaweeds</i> IV. <i>Mushrooms.</i>
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The Linnæan system of classification of plants, of which the foregoing is a sketch, although confessedly artificial, is yet so perfect that almost every form of plant can be readily referred to a place in it; but although of great use in aiding the beginner to determine the name of a plant, as if by a dictionary, it fails to recognize, what even an unscientific observer can detect—the *general* resemblances between plants, which cause them to form *Natural Families*, independent of the rules of any artificial classification. Hence, there has grown up among modern botanists, who differ widely as to their principles of classification, an agreement in opinion, that *Families* are natural as well as *Genera* and *Species*; and some botanists have gone so far as to explain the resemblances, more or less remote, known as *Family*, *Generic*, and *Specific* resemblances, by the hypothesis of *descent from a common ancestor*.

2. Natural Classification of Plants.—The natural system in Botany is based on the assumption that there are *Natural Families*, the members of which resemble each other on the whole, more than they resemble the members of any other Family; and there has been established among botanists a very general agreement as to what those families are. Jussieu, De Candolle, Endlicher, Lindley, and others, have proposed various classifications of the *Natural Families*, more or less artificial; but it is generally recognized that there is, properly speaking, only one *Natural System*—that of Nature itself, the study of which gives us an insight into the plan of the Creator. It would be impossible in an elementary work to give a description of the Natural Families themselves, or even to select examples for description among them; and I shall, therefore, content myself with a brief account of the classification of these Natural Families or Orders, into Classes according to the views of the most distinguished successors of Linnæus.

A. System of Jussieu.—According to this celebrated system,

the Vegetable Kingdom consists of 100 Natural Families, subdivided into fifteen classes, as follows :—

A.—*Acotyledons.*

Class.	Families.
I.	6

B.—*Monocotyledons.*

II. <i>Monohypogynæ</i> —stamens hypogynous,	4
III. <i>Monoperigynæ</i> —stamens perigynous,	8
IV. <i>Monoepigynæ</i> —stamens epigynous,	4

C. *Dicotyledons.*

V. <i>Epistaminæ</i> —apetalous; stamens epigynous,	1
VI. <i>Peristaminæ</i> —apetalous; stamens perigynous,	6
VII. <i>Hypostaminæ</i> —apetalous; stamens hypogynous,	4
VIII. <i>Hypocorollæ</i> —monopetalous; corolla hypogynous,	15
IX. <i>Pericorollæ</i> —monopetalous; corolla perigynous,	4
X. <i>Synantheræ</i> —monopetalous; corolla epigynous, anthers coherent,	3
XI. <i>Chorisanthæ</i> —monopetalous; corolla epigynous, anthers distinct,	3
XII. <i>Epipetalæ</i> —polypetalous; stamens epigynous,	2
XIII. <i>Hypopetalæ</i> —polypetalous; stamens hypogynous,	22
XIV. <i>Peripetalæ</i> —polypetalous; stamens perigynous,	13
XV. <i>Dielines</i> —stamens and pistils in different flowers,	5
Total,	100

B. *De Candolle's System.*—De Candolle subdivides the natural families into eight groups only, instead of the fifteen proposed by Jussieu. His first division is into Vascular and Cellular Plants.

I. *Plantæ vasculares seu Cotyledonæ.*

II. *Plantæ cellulares seu Acotyledonæ.*

The first of these groups is subdivided into Exogens and Endogens, and these again into other groups, like those used by Jussieu.

A. PLANTÆ VASCULARES SEU COTYLEDONEÆ.

I. *Exogeneæ* seu *Dicotyledoneæ*.

1. *Thalamifloræ*.
2. *Calycifloræ*.
3. *Corollifloræ*.
4. *Monochlamydeæ*.

II. *Endogeneæ* seu *Monocotyledoneæ*.

1. *Phanerogamæ*.
2. *Cryptogamæ*.

B. PLANTÆ CELLULARES SEU ACOTYLEDONEÆ.

1. *Foliaceæ*.
2. *Aphyllæ*.

Thalamifloræ are exogens, in which the petals are distinct, and (like the stamens) *inserted on the receptacle*.

Calycifloræ are exogens, having the petals distinct or coherent, and (with the stamens) *inserted on the calyx*.

Corollifloræ are exogens, with the petals coherent and inserted on the receptacle, the stamens being *inserted on the corolla*.

Monochlamydeæ are exogens, with a perianth or single circle of floral envelopes.

Endogeneæ Phanerogamæ are flowering endogens.

Cryptogamæ vasculares were supposed by De Candolle to be monocotyledons; they include the following heterogeneous families:—

1. *Naidæ*, or Pondweeds.
2. *Equisetaceæ*, or Horsetails.
3. *Marsiliaceæ*.
4. *Lycopodiaceæ*, or Club Mosses.
5. *Filices*, or Ferns.

Foliaceæ are the leafy Acotyledons, and contain—

1. *Musci*, or Mosses.
2. *Hepaticæ*, or Liverworts.

Aphyllæ are the leafless Acotyledons, and contain—

1. *Lichenes*, or Lichens.
2. *Fungi*, or Mushrooms.
3. *Algæ*, or Seaweeds.

PART III.

THE ANIMAL KINGDOM.

“ANIMALIA—Corpora organisata et viva, et sentientia, sponteque se moventia.”

“*Regnum Animale* sentiens exteriora ornat; voluntarie movetur; respirat; ova generat; pellitur iratâ fame, latâ venere, mæstoque dolore; prædando coercet vegetabilia popularesque, ut omnium proportio perennet.”—*Linnaeus*.

CHAPTER VI.

VERTEBRATE ANIMALS.

PLANTS are distinguished from Minerals by the possession of *organs and life*; and Animals are distinguished from Plants by the additional possession of a nervous system, which is capable of receiving *sensations*, and of issuing *volitions* that produce movements in special organs adapted to this use.

In the Vegetable Kingdom all the organs and life were so far similar that the description of one plant might almost be said to have served us for a general description of all plants, so that the classification of plants became subordinate to the description of organs and of their uses. In the Animal Kingdom, on the other hand, the modes of receiving sensations and of issuing volitions from the nervous system are so various, that the Classification of Animals becomes of primary importance.

*Cf Coelenterata
Protozoa etc }*

1. **Classification.**—It is, therefore, necessary to commence the description of the Animal Kingdom with a brief sketch of the classification of animals, founded on the general structure of their nervous system.

In all animals the faculties of *sensation* and *volition* reside in a peculiar kind of substance, called *nerve*, which is capable of receiving sensations and issuing volitions; and is concentrated variously into centres, called *ganglions* or *cords*, according to their shapes; the varieties of which constitute the most natural foundation for our classification. In the highest animals, the great mass of nerve substance is arranged in a long *spinal cord* enclosed in a series of bones, articulated with each other, each of which is called a *vertebra*; and the upper or anterior end of this mass of nerve substance is expanded into a bulbous portion, called the *brain*; in which the faculty of *thinking* resides, in addition to the faculties of *sensation* and *volition* possessed by it, in common with the *spinal cord*.

Aristotle was the first writer that observed this important principle of classification of animals; and he noticed, also, that animals that possessed a spinal cord enclosed in vertebræ had also *red blood*, while the animals that did not possess a spinal column had white blood, destitute of the colouring matter that characterizes the blood, or circulating fluid of the higher animals.

From the time of Aristotle, therefore, animals have been divided into two groups, named by Lamarek and Cuvier, *Vertebrate* and *Invertebrate*; of which the former have been most studied by the earlier naturalists, and the latter by modern naturalists.

In the Vertebrate animals the nervous system consists of two distinct parts; one of which presides over *animal* life, and is the instrument of thought, sensation, and volition; while the other presides over *organic* life, and regulates the functions of nutrition, circulation, respiration, and reproduction.

The first group of nerves is called the *cerebro-spinal* system, and consists of the brain and spinal cord forming a continuous body, and enclosed in the brain-case or skull, and in the series of bony rings called *vertebræ*. To this part of the nervous system belong the reception of sensations, the issuing of volitions, and the power of thought. This group of nerves is called the *Nerve System of the Animal Life*.

The second nerve system of Vertebrate animals is called the *Nerve System of Organic or Vegetative Life*; and is also known by the names *Sympathetic* or *Ganglionic System*. It is divisible into two parts placed in front of the spine; one composed of several ganglions (called *semilunar* and *cardiac*), whose branches are distributed to the primary organs of digestion and circulation; and the other consisting of two knotted cords, extended along the whole length of the spine, and communicating freely by branches with the ganglionic plexus, and with the cerebro-spinal nerves.

These two subdivisions of the sympathetic nerves are found in vertebrate animals, and are met with separately in the lower (invertebrate) forms of life. For example, in the *Mollusks*, the nervous system consists (Fig. 109) of a number of distinct ganglionic centres, joined by connecting filaments of nerve, as in the ganglionic plexus of man; and in the *Articulates*, the nervous system



Fig. 109.



Fig. 110.

(Fig. 110) assumes the form of a double row of knotted nerves, each knot corresponding to a separate joint of the body.

Neither, however, of these systems is identical with the cerebro-spinal system of the Vertebrates.

The organs of the senses are developed in the Vertebrate animals to a degree proportionate to the developement of the cerebro-spinal system. The organs of four of the senses—*sight*, *hearing*, *smell*, and *taste*—are situated in the anterior part of the head, included in bony cavities.

The sense of *touch* is in some animals especially developed in the fingers, in others in the lips, and in others probably in the tongue. The sixth or *muscular* sense, to which we owe our idea of *force*, and sensation of *fatigue*, is doubtless present in all animals endowed with muscles and capable of locomotion.

It is an especial characteristic of Vertebrate animals, that they possess an internal skeleton, of which the vertebral column forms the stem, and to the several parts of which the muscles are attached. The vertebral column and skull, with their enclosed *cerebro-spinal* cord of nerve substance, are the only essential parts of the internal skeleton, for the four limbs are wanting in most snakes and in some fishes, and the ribs are wanting in the frogs and others. The body of Vertebrate animals is generally symmetrical on the two sides, right and left; and the organs of *animal life*, the nerves and muscles, are symmetrically placed.* There are never more than four limbs; some have only

* The organs of the *organic* life are not always symmetrically placed in Vertebrate animals. Thus the heart is on the left side and the liver on the right, notwithstanding the high authority of Molière to the contrary.

GERONTE.—“ Il n’y a qu’une seule chose qui m’a choquée ; c’est l’endroit du foie et du cœur. Il me semble que vous les placez autrement qu’ils ne sont ; que le cœur est du côté gauche, et le foi du côté droit.”

SGANARELLE.—“ Oui, cela était autrefois ainsi ; mais nous avons changé tout cela, et nous faisons maintenant la médecine d’une methode toute nouvelle.”—*Le Medecin Malgré lui*.

one pair, and both are occasionally absent. The blood of vertebrates is red, and the sexes are distinct.

They have, mostly, two jaws, one situated above the other, the lower jaw having most motion; and the movement of the jaws is vertical, and not lateral, as is the case in articulate animals. The jaws are usually furnished with teeth, which in some cases, as in birds, are wanting, or replaced by horny plates.

The intestinal tube, in vertebrate animals, receives the secretions of many glands, of which the most important are, the *salivary glands*, the *pancreas*, and the *liver*. The masticated food, altered by the action of these secretions, and of the *gastric* acid of the stomach, is absorbed by delicate vessels, called lacteals, from the mucous surface of the intestines, and is carried by these vessels to the veins (especially the *left subclavian*), where it enters the general circulation of the blood, and restores to this fluid the elements it has lost by the wear and tear of daily work. Other vessels, of capillary size, and called *lymphatics*, absorb from all parts of the body a watery lymph, composed of excretions from the capillary blood vessels; and the whole lymphatic and lacteal system, of which the spleen probably forms a part, constitutes a complex system of nutrition and excretion, the details of which are but little known.

The veins having received the contents of the *lacteal* and *lymphatic* vessels, carry the blood to the heart, from which it is driven into the *respiratory* organs, where it is oxydated by the direct action of the air in *lungs*, or by the air contained in water passing through *gills*. In either case, the heart of *Vertebrates* receives unoxysided blood, and forwards it to respiratory organs, where it becomes oxydised. When the oxydised blood returns again to the heart, it is circulated by means of the arteries into all the organs of the body, which are thus fed continually by the blood, constantly replenished, through the stomach and intestines, with food, and through the respiratory organs with oxygen.

The ultimate products of all the chemical changes that take

place in the blood during the complex processes of nutrition and respiration, are—

1. Water.
2. Carbonic Acid.
- 3 Urea.

Water finds its natural outlet through the skin and lungs, as vapour ; and through the kidneys, as water.

Carbonic Acid finds its natural and healthy outlet through the lungs or gills, where it is exchanged for an equivalent amount of oxygen absorbed.

Urea, which is an excretion peculiar to the Animal Kingdom, is invariably discharged through the *kidneys*, which are organs especially devoted to this purpose. Urea has the following composition :—

Two atoms of Carbon,	12	20 per cent.
Four atoms of Hydrogen,	4	6 ..
Two atoms of Nitrogen,	28	47 ..
Two atoms of Oxygen,	16	27 ..
	<hr/> 60	<hr/> 100

Animals differ from vegetables, chemically, in the larger percentage of nitrogen that enters into their composition ; and it is a remarkable fact that this nitrogen always leaves the animal system under the form of *urea*, a substance that becomes rapidly transformed into *carbonate of ammonia*, which is readily absorbed, in turn, by plants, and so completes the cycle of chemical changes, by means of which the Animal and Vegetable Kingdoms are mutually dependent upon each other.

The organs especially appropriated to the excretion of *urea* in the Vertebrate animals are the kidneys, which are present in all animals of this class. The kidneys consist, in their internal structure, of fine tubules, which in the lower Vertebrates unite to form branches that open into excretory ducts (*οὐρητῆρες*) running along the whole kidney ; in birds and mammals, the tubules

unite to form pyramidal bundles, which are arranged round the cup-like commencements of the *ureters*; and the two ureters, again, converging from the symmetrically-placed kidneys, enter the urinary bladder, or sack, in which the secreted fluid is collected before being discharged from the body.

The Vertebrate animals are divided into four classes, originally proposed by Linnæus. This classification is natural, and based upon the temperature of the blood and internal organs; upon the various forms of the heart; upon the differences in the respiratory organs, which are either lungs or gills; and on differences in parturition, such as the laying of eggs, or bringing forth of living young.

The four classes are:—

1. Mammals.
2. Birds.
3. Reptiles.
4. Fishes.

Mammals and Birds have warm blood, and so are distinguished from Reptiles and Fishes; they are distinguished from each other by the Mammals being viviparous, and the Birds being oviparous.

Reptiles and Fishes have cold blood; and are distinguished from each other by the Reptiles having lungs, and the Fishes having gills.

2. Mammals.—The Mammals are the highest form of animal life, and include Man himself; they are vertebrate warm-blooded animals, breathing by means of lungs; and they differ from Birds in having a muscular midriff or diaphragm, separating the cavity of the chest from that of the belly; or dividing the internal organs of circulation and respiration from those of digestion and reproduction. Mammals differ also from birds in having glands (*mammæ*) which secrete the milk, with which the mother feeds her young; and in being viviparous, instead of oviparous.

A. *Skeleton*.—The skeleton of mammals consists essentially of a series of bones, articulated with each other, called vertebræ, which enclose the brain and spinal cord; together with four limbs, or locomotive organs, which undergo great modifications, according to the uses to which they are destined to be applied.

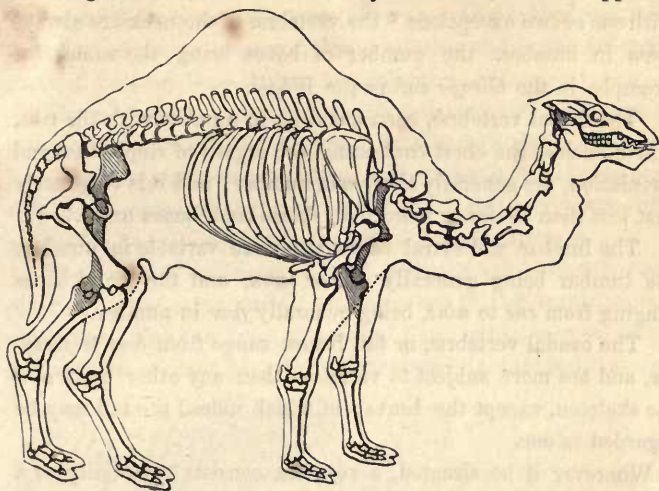


Fig. 111.

Figs. 111 and 112, representing the skeletons of the *Camel* and

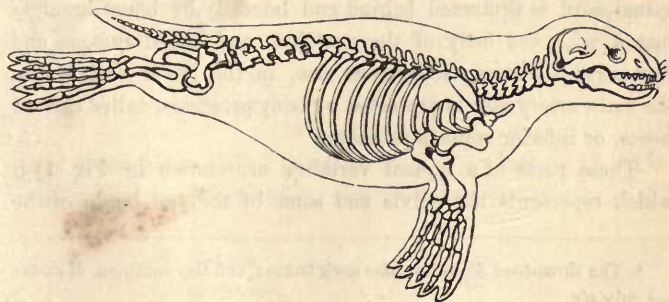


Fig. 112.

of the *Seal*, serve to show the plan on which the whole skeleton

is constructed, and also the modifications undergone by the limbs, according to the requirements of the locomotion proper to the element in which the animal lives.

The skull, composed of numerous bones, encloses the brain, and is followed by the cervical vertebræ composing the neck; with one or two exceptions,* the vertebræ of the neck are always *seven* in number, the number of bones being the same, for example, in the *Giraffe* and in the *Whale*.

The dorsal vertebræ, corresponding in number with the ribs, which enclose the chest containing the organs of respiration and circulation, are generally *thirteen* in number; and it is very rarely that less than *twelve* or more than *fifteen* back bones occur.†

The lumbar and sacral bones are more variable in number, the lumbar being generally *six* or *seven*, and the sacral bones ranging from *one* to *nine*, being generally *four* in number.

The caudal vertebræ, or tail bones, range from *four* to *forty-six*, and are more subject to variation than any other portion of the skeleton, except the limbs; of which indeed the tail may be regarded as one.

Wherever it be situated, a vertebra consists essentially of a *body* or *centrum*, on the back of which the spinal cord lies, and generally in front of it the main artery of the trunk; the spinal cord is protected behind and laterally by bones amalgamated with the body of the vertebra, and called *spinous* and *transverse* processes; sometimes also, in the lower vertebrates, the main artery also is protected by bony processes, called *chevron* bones, or *inferior spinous* processes.

These parts of a typical vertebra are shown in Fig. 113, which represents the pelvis and some of the tail bones of the

* The three-toed Sloth has *nine* neck bones; and the southern Manatee has only *six*.

† One of the Armadilloes has only *ten*, the Pachyderms have from *eighteen* to *twenty-one*, and the Sloths have *twenty-four* back bones.

alligator; the bodies of the vertebræ are marked *b*, the spinous processes *sp*, the transverse processes *tr*, and the chevron bones *ch*.

These various parts of the vertebra serve not only for the protection of the spinal cord and abdominal aorta, but also form the origins and insertions of muscles, that move the head, the tail, and other parts of the vertebral axis. Their developement, therefore, varies greatly in different animals and in the different parts of the back bone of the same animal.

The *ribs* are appendages of the dorsal vertebræ, and enclose the cavity of the chest; they are usually articulated with the bodies of two successive vertebræ, and with the transverse process of the posterior of the two vertebræ. Anteriorly, the ribs are united by cartilages with the breast bone, or *sternum*.

The posterior and anterior pairs of limbs are evidently constructed on the same model, and attached to the trunk in the same way. The best type of the hind limb, or leg, may be found in the order of Reptiles. It is articulated to the body at the

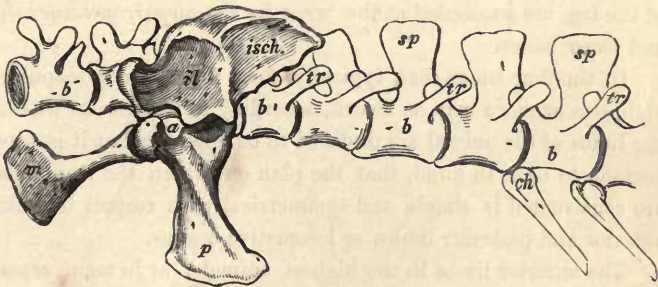


Fig. 113.

cavity of the *pelvis*, called the *acetabulum* (*a*). The pelvis is, in the Alligator, composed of four distinct bones, named—

<i>Ilium</i> ,	<i>il</i> .
<i>Ischium</i> ,	<i>isch</i> .
<i>Marsupial</i> ,	<i>m</i> .
<i>Pubes</i> ,	<i>p</i> .

and is shown in Fig. 113.

The head of the thigh bone, or *femur*, plays in the socket, formed by the *ilium* and *pubes*. The thigh bone is succeeded at the knee-joint by the leg bones, *tibia* and *fibula*, and these again are followed at the ankle by the *tarsal*, *metatarsal*, and *toe* bones.

The best type of the anterior limb is to be found in Birds, in which the office of the wing is predominant. The arm bone, or *humerus*, of the bird plays in a socket, formed of four bones that correspond to the four bones of the pelvis of the reptile, viz. :—

<i>Acromion</i> ,	<i>ilium</i> .
<i>Scapula</i> ,	<i>ischium</i> .
<i>Clavicle</i> ,	<i>marsupial</i> .
<i>Coracoid</i> ,	<i>pubes</i> .

It is, fortunately for the learner, not necessary to know all the details of the relation of the fore limbs to the hind limbs in mammals; and it is sufficient to observe their general analogy. The arm bone is followed, at the elbow-joint, by the two bones of the forearm, *radius* and *ulna*; and these again, like the bones of the leg, are succeeded at the wrist by the *carpal*, *metacarpal*, and *finger* bones.

Of the four bones that, typically, form the pelvic or scapular arch, one or more may be absent, according to the uses to which the limbs of the animal are destined to be applied; but it is important to bear in mind, that the plan on which the mammals are constructed is simple and symmetrical with respect to their anterior and posterior limbs, or locomotive organs.

The anterior limbs in the highest animals, as in man, cease to be used as locomotive organs, and are devoted to serve the brain, by a process described by Prof. Dana, as *cephalisation of the fore limbs*; and he considers that animals ought to be classed in order of dignity, in proportion as their fore limbs are appropriated, as organs of prehension, instead of organs of locomotion. The anterior limbs are never absent in mammals, but they are frequently destitute of a *clavicle*, and the *acromion* is often reduced to be a mere process of the *scapula*. The *coracoid*, which in birds and reptiles acts the part of a second clavicle, is found

as a distinct part of the scapular arch, in the *Monotremes* only among mammals.

The arm bone and thigh bone resemble each other, and also the double bones of the forearm and leg, which admit of a rotation, more or less perfect in different animals, being accomplished.

The bones of the wrist and ankle, and of the hand and foot, fingers and toes, are subject to many variations, which are of the highest value in classification.

The fingers vary in number from one to five; in the *Horse* they are reduced to one, which is regarded as the middle finger; in the *Ox*, two fingers, index and middle, are constantly present, with rudiments of two other imperfect fingers.

The toes undergo similar modifications, and do not always correspond with the fingers; thus the *Leopard* has five fingers and only four toes; the *Hyæna* has four fingers and four toes.

B. *Nervous System*.—The nervous system of mammals consists, as already described, of two parts—

a. Cerebro-spinal system.

b. Sympathetic system.

(a). *Cerebro-spinal System*.—The brain and spinal cord of man and the higher animals, Fig. 114, form a central mass of nerve substance, from which the nerves of *volition* branch out in all directions to the muscles, and towards which the nerves of *sensation* converge from all parts of the body. These nerves have been very ridiculously compared by popular writers to telegraph wires, and the brain to a galvanic battery that works the wires. The influence that travels along the nerves bears no resemblance whatever to an electric current, for it moves only at the rate of 90 ft. per sec., which is less than the tenth part of the velocity of sound in air;*

* The volition and sensation move along the nerves at about the same rate as sound would be propagated in the nerve. The velocity of sound in Indianrubber softened is found to be 90 ft. per second.

whereas the velocity of the electric current is considered to be 10,000 times that of light, which is nearly 200,000 miles per second!

There can be no doubt that it is a *chemical* action that is propagated to and fro along the nerves, and that each message of volition and sensation is accompanied by a chemical change, and consequent loss of force that must be compensated for by fresh additions of new materials in the form of food. Branch nerves are given off by the spinal cord at each vertebra, and several of these pairs of nerves unite in the neck and loins, to form origins for the great brachial and sciatic nerves that supply the anterior and posterior limbs.

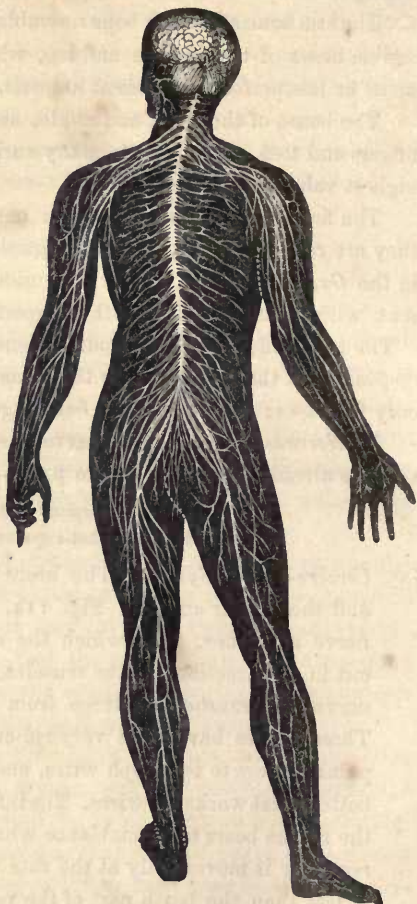


Fig. 114.

The weight of the brain, as compared with that of the whole body, is as follows in several animals—

Man,	1 to 40
Ox,	1 to 860
Elephant,	1 to 500
Sheep,	1 to 350
Fox,	1 to 205
Mouse,	1 to 43
Green Monkey,	1 to 40
Bonnet Monkey,	1 to 27

The cerebro-spinal system of nerves presides over what is called the *animal* life, including thought, sensation, and volition.

(b.) *Sympathetic System*.—This system of nerves presides over what is called the *Organic* or *Vegetative* life, and regulates digestion, respiration, circulation, and reproduction. It consists of two distinct parts, the *ganglionic* system and the great *sympathetic*; the former resembles, Fig. 109, the nervous system in the Molluscous animals, and is situated in great part in the cavities of the chest and belly, following the course of the blood vessels, whose rate of action it regulates. Its most important ganglion is called the *solar plexus*, which lies immediately behind the stomach, round the coeliac artery; this great plexus is believed by some to be the seat of the nerve poisoning that constitutes the disease known as *Asiatic Cholera*. The *great sympathetic* consists of a number of double or knotted ganglions, arranged in pairs along the whole length of the vertebral column. There are three of these important ganglions in the neck, called the upper, middle, and lower cervical ganglions; these are intimately associated with the tenth pair of nerves proceeding from the cerebro-spinal axis, and called the *pneumogastric* nerve, because, in conjunction with the cervical ganglions of the great sympathetic, it regulates respiration and digestion. Not only in the neck, but along the entire cord, the sympathetic and cerebro-spinal systems are united by means of interlacing filaments, so that throughout the entire body the most perfect harmony is kept up, during health,

between the motive principles of the animal and of the organic life.

C. Respiration.—This function is performed by means of lungs, *l, l*, Fig. 115, which, with the heart, *h*, are placed in the cavity of the chest above the diaphragm; the external air enters the windpipe through the mouth or nose, and is distributed by means of bronchial tubes through the substance of the lungs. In mammals, the bronchial tubes undergo a very minute subdivision, so that the

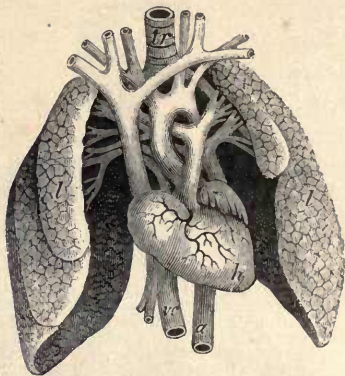


Fig. 115.*

venous blood pumped into the capillaries of the lungs by the right side of the heart, is forced into close contact with the fresh air distributed through the minute bronchial tubes, and so becomes rapidly oxydised.

The average amount of air contained in the lungs is 230 cubic inches, and of these, thirty cubic inches are renewed at each inspiration and expiration, so that at the end of eight breathings the whole air in the lungs is changed; and as we make about sixteen inspirations in a minute, the whole air in the lungs is twice changed every minute. On examining the chemical composition of the expired air, it is found to have gained four per cent. of carbonic acid, and to have lost a little more than four per cent. of oxygen. The carbon thus excreted from the body is estimated in the course of a day spent in usual labour, at 8 oz. or half a pound; and it is believed that, in health, the lungs form the only exit for carbonic acid.

The carbonic acid discharged from the lungs is really, like

* Fig. 115—*Lungs and heart of Man.* *l, l*, the lungs; *h*, the heart; *tr*, the trachea or windpipe; *vc*, the vena cava inferior; *a*, the abdominal aorta.

other excretions, formed in the blood, and not in the lungs themselves; and its elimination is so necessary to life, that an immersion in water of sixty seconds will kill a man, although the lower animals will bear a longer immersion with impunity. In other words, the accumulation in the blood of the carbonic acid formed in one minute, corresponding to twice the contents of the lungs, will so poison the blood, that the brain ceases to act, and death ensues by coma.

Inspiration and expiration are effected, partly by means of intercostal muscles, raising and lowering the ribs, and thus increasing or decreasing the cavity of the chest, and partly by means of the muscular diaphragm peculiar to mammals, which by its contraction enlarges the chest, and aids inspiration.

We thus see how respiration in the animal kingdom is complementary to respiration in the vegetable world, and that they are mutually dependent on each other, alternately forming and unforming carbonic acid for each other's use.

D. *Circulation*.—The heart of mammals, Fig. 116, is double; the right side consisting of two cavities, the right auricle *ra*, and the right ventricle *rv*, separated from each other by a large orifice called the auriculo-ventricular opening; and the left side consisting of two similar cavities, the left auricle *la*, and the left ventricle *lv*, separated from each other by a similar auriculo-ventricular opening.

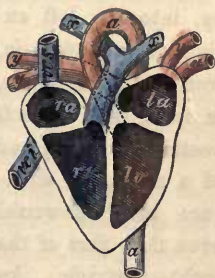


Fig. 116.*

The right auricle, *ra*, receives the blood from the entire body, poured into it by two large veins called superior vena cava, *vcs*, and inferior vena cava, *vci*; the venous blood, loaded with carbon, is passed from the right auricle into the right ventricle, the

* Fig. 116—*Diagrammatic Representation of the Heart.* *ra*, *rv*, the right auricle and ventricle; *vcs*, *vci*, the venæ cavæ; *xx*, the pulmonary arteries; *la*, *lv*, the left auricle and ventricle; *yy*, the pulmonary veins; *aa*, the aorta.

walls of which are composed of a powerful muscular structure, which contracts and propels the blood from the heart into the lungs, through the pulmonary arteries *xx*, while it is prevented from passing back again into the right auricle, by a valvular structure consisting of three flaps, and called the *tricuspid* valve; the blood having undergone, by oxidation in the lungs, the change converting it from venous into arterial blood, is returned through the pulmonary veins, *yy*, *yy*, into the left auricle of the heart, *la*, from which it passes, in turn, into the left ventricle, *lv*, composed of a muscular structure more powerful even than that of the right ventricle; by which it is propelled through the great aorta, which is shown at *aa*, Fig. 116, through the arteries of the whole body, as shown in Fig. 117, carrying

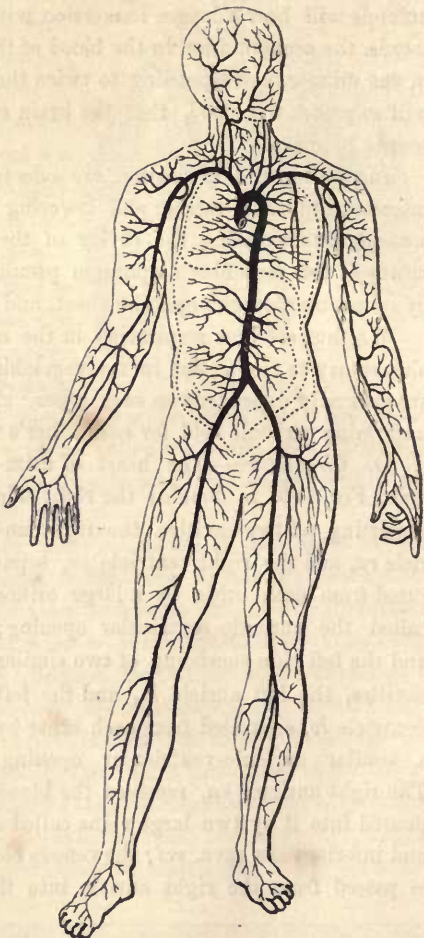


Fig. 117.

with it the elements of fresh nutrition to every minute part. The arterial blood is prevented from regurgitating into the left

auricle by a valvular structure, similar to that of the right auriculo-ventricular opening, but consisting of only two flaps, whence it is called the *bicuspidæ*, or *mitral valve*. The openings of the pulmonary artery into the right ventricle, and of the great aorta into the left ventricle, are closed by three valves, called the *semilunar valves*, which, in health, prevent a single drop of blood from returning back into the heart, when the contraction of its ventricles has ceased.

The walls of both ventricles contract simultaneously, propelling the venous blood into the lungs, and the arterial blood through the arteries of the whole body; when their contraction has ceased, the auricles contract in turn, but with much less force, upon the blood sent in by the *venæ cavæ*, and by the *pulmonary veins*, and, by their contraction, refill the empty ventricles, which again contract as before; and so the circulation, both in the lungs and in the body, is kept up by a system of pulsations, rythmical in character, and differing in different animals, and at different periods of life.

The form of the heart is various; it is broad in the cetaceans and elephant, elongate in the dog, and round in monkeys, while it is obtusely conical in the horse, ox, orang outan, and in man. Previous to birth, the pulmonary circulation provided by the right side of the heart is useless, and, consequently, the two auricles communicate before birth by an opening, which closes shortly after birth, leaving a scar or pit, called the *foramen ovale*: in seals and other animals that remain long under water, and require less oxydation of their blood than other animals, the foramen ovale remains sometimes open through life; and in man, the same circumstance is occasionally observed, as the result of some congenital defect. In such cases, the mammal is partially reduced to the condition of a lower form of vertebrate animal, and the oxydation of the blood is most imperfectly accomplished, a portion of the whole blood only being transmitted through the lungs at each pulsation.

The heart of man has been computed, in the course of a day, to give out a quantity of work equivalent to lifting 122 tons through one foot; but both in man and animals its work varies with occupation and age; thus, the hearts of cab horses are found to be more muscular and larger than those of dray horses worked at walking pace; and it is well known that the heart of man grows heavier and more muscular with advancing years, because more and more work is thrown upon it by reason of the increasing rigidity of the arteries, which are less elastic than in youth.

E. *Digestion*.—Having considered the apparatus by which carbonic acid is excreted from the system, and the blood oxydised in the lungs; and also the mechanism by which the entire blood is pumped perpetually through both lungs and body; it remains to examine briefly the process called *digestion*, in which may be included the excretions formed by the liver, by which certain elements, as hydrocarbons, are removed from the blood, and thrown out of the body, in a manner not unlike that in which carbonic acid was shown to be excreted by the action of the lungs.

The food received by the mouth is passed into the stomach, and thence through the intestines, undergoing a variety of changes in its passage; by means of which certain portions of it are absorbed into the blood, and so form the fresh materials by which the tissues of the body are repaired. The order in which the parts of the alimentary canal, from the mouth downwards, or backwards, are arranged, is the following:—

- a. Mouth.
- b. Pharynx and Œsophagus.
- c. Stomach.
- d. Duodenum.
- e. Small Intestines.
- f. Cæcum.
- g. Colon and Rectum.

The total length of the intestinal canal varies much in different animals; in *Man* it is usually 30 feet in length, and is

longer in the herbivorous than in the carnivorous animals; thus, in the *Ox* it is 150 feet in length, and in the *Lion* only 18 feet long. The length of the alimentary canal seems to depend also on its diameter; for in the *Hyæna*, *Seal*, and *Otter*, which are carnivorous animals, although the canal is unusually long, yet it is remarkably narrow, so that the amount of absorbing surface, with which the food is brought in contact, is not really greater than in other carnivorous animals endowed with a smaller length of intestine.

- (a.) *The Mouth*.—In the mouth of mammals, the food is subjected to the process of maceration by the salivary glands, and of mastication by the teeth. With the exception of the *cetaceans*, all mammals are provided with salivary glands, which are more highly developed in proportion as the food is subjected to a more or less prolonged mastication. In man, the salivary glands are three in number, at each side of the mouth, viz., the *parotid*, the *submaxillary*, and the *sublingual* glands. The secretions of these glands, in all mammals, consist of water, salts, mucus, and from one to two per cent. of a peculiar principle, called *salivine*, which has the property of converting the starch of the masticated food into sugar.
- (b.) *The Pharynx and Œsophagus*.—The commencement of the alimentary canal, behind the mouth, consists of a wide muscular bag called the *pharynx*, which passes downwards into the narrower tube called the *œsophagus*, which, like the pharynx, is very muscular, and capable, by means of a vermicular movement, of propelling the food, transmitted to it from the mouth, into the stomach. Its muscular coat, in most mammals, consists of two concentric portions, in which the muscular fibres are spirally arranged and run in opposite directions; in Man, however, it consists of an external coat of longitudinal fibres, and an internal coat of transverse circular fibres. The action of the pharynx and œsophagus

with respect to digestion is purely mechanical, as no secretion is poured into the food, except that of the salivary glands, before it reaches the stomach. The œsophagus penetrates the diaphragm, and immediately afterwards enters

(c.) *The Stomach.*—The general arrangement of the *stomach*, and other organs of digestion, below the diaphragm, are shown in Fig. 118, which is drawn from the *Otter*. In this diagram—

dd, represents *diaphragm*;
lll, „ different lobes
 of the *liver*;
ss, „ *stomach*;
sp, „ *spleen*;
k, „ *right kidney*;
b, „ *urinary bladder*;
g, „ *gall bladder*.

The internal coat of the stomach secretes, copiously, when food is introduced, a liquid called *gastric juice*, the active principles of which are known as *lactic acid* and *pepsine*. These substances, acting upon the nitrogenous parts of the food, such as *fibrine*, *albumen*, and *gelatine*, convert them into a substance called *peptone*, capable of being assimilated when received into the blood.

Thus, the special function of the *salivary glands* is to digest the *starch* compounds of the food; and the special function of



FIG. 118.

the *gastric juice* is to digest the *nitrogenous* elements of the food ; the remaining, or *fatty* elements of food, are, in like manner, digested, and prepared for assimilation by the *pancreatic* juice.

The form of the stomach differs much in different mammals ; in the kangaroos, it is elongate, and resembles a part of the large intestine ; and in some Bats, Monkeys, and Sloths, it is divided into several compartments by constrictions, but it is in the Ruminants that the stomach becomes really compound, and deserves particular notice. In these animals, the *first* stomach, called the *paunch*, lies on the left side, terminates in two blind sacks, is very large, and is covered on the inner surface with horny papillæ ; the *second* stomach, called the *honeycomb*, is much smaller, lies on the right side of the paunch ; it is round, and is covered on its inner surface with six-sided cells that give to it the name of *honeycomb* ; between the *first* and *second* stomach, the opening of the œsophagus is placed, so that the food descending from the mouth can be “shunted” at pleasure into either one or other stomach. On the right side of the *honeycomb*, lies the *third* stomach, called the *manyplies* ; it is elongate and covered on the inside with many broad, longitudinal folds, arranged like the leaves of a book ;* the *manyplies*, or *third* stomach, communicates with the *honeycomb*, or *second* stomach, by a narrow opening ; while it communicates with the *reed*, or *fourth* stomach, by means of a very wide opening ; the *fourth* stomach is of considerable size, and resembles in shape the stomach of *Man*, or of the *Otter*, shown in Fig. 118. It possesses longitudinal folds that secrete *gastric* juice, like ordinary stomachs ; and in the young animal, fed on milk, is the largest and most important of the four. Daubenton proved, by

* These leaves are of different sizes, as if books of different kinds had been bound together ; in the ox, there are ninety-six leaves in all ; twenty-four large, forty-eight small, and twenty-four of middle size.

feeding different lambs on grass and on milk, that the *paunch* remained undeveloped, so long as the milk food was used. The paunch may be regarded as a reservoir of food (similar to the *buccal* pouches of some monkeys), in which the store of food is macerated before being chewed ; and Ruminants possess the power of regurgitating the food from the paunch into the mouth, for mastication, at pleasure. The *third* and *fourth* stomachs, or *manyplies* and *reed*, are united into one, both in the *Llama* and in the *Camel*.

It is remarkable that the juices secreted by the *paunch* and *honeycomb* are alkaline, like the saliva ; while those secreted by the *manyplies* and *reed* are acid, like the gastric juice.

The food, masticated by the teeth, having had its starch converted into sugar by the saliva, and its nitrogenous parts converted into peptone by the gastric juice, is finally transferred as a pulpy mass called *chyme* through a muscular valve called the *pylorus* (πυλῶρος) into the

(d.) *Duodenum*, or commencement of the small intestines. The *pancreas*, or *whitebread*, is a narrow flat gland, extending across the abdomen under the stomach ; and possesses a duct traversing the entire length of the gland ; its secretion is poured into the duodenum, together with that of the liver, shortly below the pylorus, and possesses the special function of digesting the fatty portions of the food. This important fact is proved by many experiments on animals ; thus, in dogs from which the pancreas have been removed, the fat used in food is found to be passed, unaltered, on defecation ; and in patients suffering from diseases of the pancreas that destroy its action, the same phenomenon is observed ; and both dogs and patients rapidly grow thin, from the cessation of the pancreatic juice, which in health assimilates the fatty and oily constituents of the food. The pancreatic juice possesses also the same action upon starch, that belongs to the saliva, so that any portions of starchy food that may have

escaped conversion into sugar during the process of mastication are acted upon by the pancreas, and the process of conversion of starch into sugar completed.

- (e.) *Small Intestines*.—The portions of the small intestines below the *duodenum* are called the *jejunum*, and the *ileum*, which latter name continues as far as the *cæcum*, where the large intestines commence, and are usually separated from the small intestines by a valve called the *ileocæcal* valve, which allows the contents of the small intestines to pass into the *cæcum*, but prevents their return. Through the entire length of the small intestines absorption of the digested food takes place by the capillary lacteals; and certain little known secretions are added to it by the surface of the intestines themselves. In order to increase the absorbing surface, the interior of the intestine is arranged in a series of valve-like folds, so as to bring the food into contact with as large an absorbing surface as possible.

The digested food, in passing from the stomach, is called *chyme* (*χύμος*), and possesses an acid reaction, due to the excess of gastric juice; when the chyme has received the secretion of the pancreas, and the excretion of the liver (*bile*), it acquires a slightly alkaline reaction which it retains through the whole of the small intestines, and is called *chyle* (*χυλός*); it owes its alkalinity to the *bile*, which possesses a feebly alkaline reaction.

- (f.) *The Cæcum*, as the name implies, is a blind *cul de sac*, placed at the commencement of the large intestines, and the food which has passed the *ileocæcal* valve is subjected in the *cæcum* to a second coction, which has been compared to a second stomachal digestion. The surface of the *cæcum* secretes an acid juice, which counteracts the alkalinity of the *chyle*, and also secretes the oils that give to the *fæces* of each animal their characteristic odour.

The *cæcum* of different kinds of mammals is very different,

and it is therefore of much value in classification. One of the *Anteaters*, like the birds, possesses two cæca; in *Hyrax* there is a short wide cæcum, in the usual position, while lower down, in the large intestine, there are two other blind and conical appendages placed side by side.

(g.) *The Colon and Rectum*.—The large intestine is divided into the ascending, transverse, and descending *Colon*, and the *Rectum*; shown, diagrammatically, in Fig. 119.

Ascending Colon,	A.
Transverse Colon,	T.
Descending Colon,	D.
Rectum,	R.
Stomach,	S.
Duodenum,	d. d.
Small intestines,	I.
Cæcum,	C.
Vermiform appendix of cæcum,	v. a.

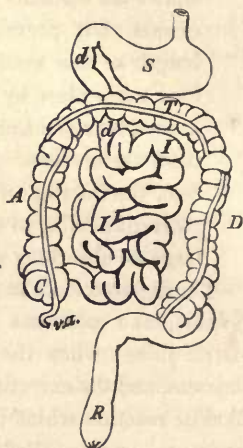


Fig. 119.

The longitudinal muscular fibres of the *colon* are arranged into three bands, which are shorter than the walls of the intestine itself, so that the latter is thrown into puckers and pouches; and in the *rectum*, there is a remarkable arrangement of the circular fibres at the termination of the gut, well known as the *sphincter* muscle, which keeps the aperture firmly closed, except when defecation takes place.

It must not be supposed that all absorption of food ceases with the small intestines, although as a rule it does so; for many instances are on record—as, for example, in cases of closure of the œsophagus—of persons having been kept alive for months by injections of warm milk and calf's head soup into the *colon*, when it was impossible to administer food in any other way.

F. *The Liver and Kidneys*.—The *liver* constitutes the largest

gland in the bodies of most animals, and serves a double purpose—that of forming a secretion necessary to the complete digestion of the food, and an excretion of hydro-carbons from the blood. It is situated below the diaphragm, Fig. 118, *U*, chiefly on the right side, and is sometimes divided into lobes, as in the carnivorous animals; the secretion of the liver, called *bile*, is in many animals collected into a gall bladder; but this organ is often wanting, as in the Whale, the Elephant, the Sloth, and the Deer. The bile ducts open into the duodenum at the same place as the pancreatic duct, and the two secretions seem to act simultaneously on the *chyme* poured out from the stomach. Bile is found to consist principally of *biline*, composed essentially of two organic acids, *Taurocholic* and *Glycocholic*, one of which contains sulphur and the other does not; and of a peculiar crystallized fatty substance called *cholesterine*, which forms the substance of gall stones: in addition to biline and cholesterine, the bile contains water, saline, and colouring matters, which, with the cholesterine, are to be regarded as excretions, while the biline is to be regarded as a secretion necessary to digestion.

Cholesterine, and the salts of bile are found in the blood, just as the carbonic acid excreted by the lungs, and the urea excreted by the kidneys are found in the same fluid; hence, so far as these substances are concerned, the liver plays the part of a simple excreting organ, separating from the blood, substances pre-existing in it, and rejecting them from the body.

The total quantity of bile excreted by a healthy man in twenty-four hours is estimated at something under 40 oz. (16940 grs.); of which 10.469 grs. are pure cholesterine, and have been found by direct experiment to be represented by 10.417 grs. of *stercorine* actually discharged from the body.

The quantity of biline secreted by the liver in one day, corresponding to the 10 grs. of cholesterine excreted, amounts to 1345 grs., the whole of which is employed in modifying the products of digestion, and in forming *chyle*, and is again re-absorbed

from the intestinal surface, and reintroduced into the blood. The liver is supplied both with arterial and venous blood, and performs, as we have seen, the double function of secretion and of excretion. Biline is not found in the blood, and is therefore to be regarded as a pure secretion, formed by the liver itself. It is a remarkable fact, that the blood that leaves the liver after the elements of biline and cholesterine have been abstracted from it, contains a larger quantity of sugar than the blood that enters it; as if the sugar also (*glucose*) were a product of the chemical changes that produced the proper secretions of the liver.

The *Kidneys*, in mammals, are situated in the lumbar region, Fig. 118 *k*, outside and behind the sack that contains the intestines. In many mammals the right kidney is higher up than the left, but in man the reverse is observed; they are surrounded by a loose areolar tissue in which much fat is accumulated, highly prized by gourmands. In the human embryo, the kidneys consist of several masses or lobes, and in some animals they continue in this condition through life, as in the Seal and Bear. It is the special function of the kidneys to excrete *nitrogen*, in the form of the compound called *urea*; just as it is the function of the lungs to excrete carbon in the form of the compound called carbonic acid. The daily excretion of urine in man is about 40 oz., or the same as the secretion of bile; and these 40 oz. of urine contain 500 grs. of urea, having the composition—

Two atoms of Carbon, . .	12 . .	20 per cent.
Four atoms of Hydrogen, . .	4 . .	$6\frac{2}{3}$ „
Two atoms of Nitrogen, . .	28 . .	$46\frac{2}{3}$ „
Two atoms of Oxygen, . .	16 . .	$26\frac{2}{3}$ „
	<hr/> 60	<hr/> 100
	—	—

The importance of the due excretion of urea cannot be exaggerated, for it forms practically the only outlet for the nitrogen that constitutes so large a portion of our food, and its retention in the

body is quickly followed by coma and death; less rapid only than that which follows the retention of carbonic acid.

There are three, and only three, excretions of Mammals essential to life and health : viz. *water*, *carbonic acid*, and *urea* ; of these, *water* is excreted by the lungs, kidneys, and skin ; *carbonic acid* is excreted by the lungs ; and *urea*, by the kidneys. It is only for a short period, and then near the close of life, that any of these organs can take upon itself the functions of the others : when this occurs, unless the cause of the derangement be temporary, death shortly closes the scene, and stamps with his seal the unchangeable fiat of the Creator.

3. Classification of Mammals.—Mammals are divided into two great subdivisions—

- I. Placental Mammals.
- II. Non-Placental Mammals.

In all mammals of the placental class the young is nourished in the womb of its mother by means of a remarkable structure called the *placenta*, which consists of very vascular tissue, in which the arterial blood provided by the circulation of the mother, is passed through minute capillary vessels that increase in size like veins, before they unite to enter the circulation of the young. The young of *placental* mammals are thus nourished with the mother's arterial blood, until, when born, they are able to seek their nourishment, by sucking the mother's teats. In the *nonplacental* mammals, on the other hand, the young are not nourished by a placenta in the womb, but are born in an immature condition, and fastened by the mother herself upon the teat, which they are unable to suck by their own efforts ; and therefore the milk is squeezed, by a muscular exertion on the part of the mother, into the mouth of the young until mature. It is also noticeable that the supplying of the young with milk, is not left merely to an instinct of the mother, but is effected also, involuntarily, by each movement of

the hind limbs. The placental Mammals are divided into the following orders :—

I. *Placental Mammals.*

A. Man.

B. Quadrumans . . .	C. Chiropters.
D. Carnivores . . .	E. Insectivores.
F. Ungulates . . .	G. Rodents.
H. Mutilates . . .	I. Edentates.

A. MAN.—*Has the incisor, canine, and molar teeth even, contiguous; molars equally enamelled; incisors four in each jaw. Feet five-toed, anterior limbs furnished with five-fingered hands; nails all flat, broad. Gait erect. Placenta deciduate, discoidal.*

Man is distinguished from all animals by his moral and reasoning faculties, but, anatomically, the distinction between man and the lower animals is much less than his moral and intellectual superiority would lead us to expect. He possesses an erect gait, such as is unknown even among the highest monkeys, and this circumstance sets free his hands to minister to his intellectual wants, instead of being used as instruments of locomotion. The articulate speech of man, based upon the universal laws of grammar, is the simplest exponent of his reason; and through means of speech man possesses traditions and a history, and becomes capable of progressive improvement in civilization. Blumenbach considers that there are five races of men—Caucasian, Mongolian, Æthiopic, American, and Malay—and most naturalists believe (independently of tradition) that the differences between these races are not sufficient to entitle them to be regarded as distinct species.

B. QUADRUMANS.—*Possess incisor, canine, and molar teeth; molars equally enamelled. Feet unguiculate, either all pentadactylous or only the posterior, with anterior tetradactylous. Thumb in the pentadactylous feet remote from the other fingers, with nail flat. Pectoral mammæ. Placenta deciduate, discoidal, lobate.*

These animals include the monkeys, apes, &c., animals which

are called quadrumanous, because their hind feet grasp objects in climbing, after the manner of hands; thus they are *four-handed* mammals. The whole order is intended to live in trees in tropical regions, a mode of life, for which the structure of their feet, and the prehensile tails of many of them peculiarly adapt them. They are found in the forests and rocky deserts of Southern Asia, Africa, and South America, where they live in troops, and feed principally on fruits. It is remarkable, that while the teeth of most of the monkeys of the Old World agree in number with those of man, the monkeys of the New World have three false molars, instead of two, at each side of each jaw.

The Quadrumans differ remarkably from man in the action of their feet, having free thumbs opposable to the other toes, which are long and slender, like the fingers of the hand. They therefore climb branches of trees with facility, but cannot stand or walk erect without much difficulty, for in this position the soles of the feet are nearly opposed to each other, and the feet rest on their outer edges, while the narrow pelvis is very unfavourable to equilibrium in the erect posture. The intestines and viscera of the quadrumans, with some exceptions, are similar to those of man—so much so, that several of the descriptions of Galen, founded on the dissection of Barbary Apes, have been supposed to be taken from the human body. The brain of the higher monkeys is very like that of man—so, like indeed, as to demonstrate how little we know of the real connexion between the brain and the intellect, of which it is the instrument; for no anatomical evidence exists to explain the profound difference between these animals and man.

The Quadrumans include the following sub-orders:—

1. *Strepsirhine Quadrumans*, having twisted or curved terminal nostrils, and the second toe of the foot converted into a claw. Example—*The Lemur*—Madagascar. The Lemurs inhabit Madagascar, and a few of the smaller islands in its vicinity, in which they fill the place of monkeys,

none of which exist in Madagascar. They live, like the monkeys, in troops upon the trees, and feed upon fruits and insects. In captivity they are very affectionate and good-tempered, fond of being noticed, and exceedingly active, leaping from point to point, alighting without noise. They are nocturnal in habit, and pass a considerable part of the day in sleep. When two of these animals are confined together, they interlace their legs and tails in a singular fashion, placing their heads so that each can see, if disturbed, what takes place behind his neighbour's back, and so they take their diurnal nap.

2. *Platyrrhine Quadrumans*, having the nostrils subterminal and wide apart, the thumb of the hand not opposable or wanting, and the tail prehensile. Example—the *Capuchin Monkey*—South America.

The Capuchin Monkeys, or *Sapajous*,* live in the forests of South America, and differ from the monkeys of the Old World in the number of their pre-molar teeth, and in their prehensile tails. Their hands are inferior to those of the other monkeys, because the thumb is not opposable to the fingers; they are small in size, and playful in disposition, and lead a merry life, springing in flocks from tree to tree, and feeding upon fruits, insects, and eggs of small birds, of which they are the natural enemies. The species called Capuchin has a black hood of hair round its face, and has a habit of crossing its long arms upon its breast, as if in the attitude of prayer, from which habit it has received the name of Capuchin Monkey.

3. *The Catarrhine Quadrumans*, with oblique nostrils and approximated below, opening above and behind the muzzle; thumb of hand opposable. Examples—*Baboon*—Africa and Asia.

This sub-family of Quadrumans inhabits the Old World,

* These are believed to be the happiest animals that God has created.

and agrees with man in many points of structure ; it also includes the celebrated anthropomorphous apes, *Gorilla*, *Orang Outang*, and *Chimpanzee*. Of these, the faces of the Orang and Chimpanzee are very human, while young, but lose this character as age advances, in consequence of the growth of the bony ridge, to which the temporal muscles are attached, which close the jaw ; the growth of these ridges gives a savage and ferocious expression to the adults of all the Catarrhine Apes, the males of which have large canines to match their temporal muscles ; and are, as a class, much less gentle and playful than the innocent Lemurs and Capuchins.

C. THE CHIROPTERS.—*Incisor teeth various in number; canines distinct; molars uniformly enamelled, multicuspidate or furnished with crown depressed. Feet five-toed. Bones of arms and fingers elongate, sustaining a large membrane serving as a wing for flight; fingers, except thumb, furnished with claws; toes short, all furnished with claws. Two pectoral mammæ. Placenta deciduate, discoidal.*

The Bats, or *wing-handed* mammals, form a very natural group, and are so named from the elongation of four fingers of the hand, for they fly by means of the membrane attached between the ex-



Fig. 120.

tended fingers of the hand, Fig. 120, while the thumb remains of the ordinary size. Although their hands are chiefly devoted to

the purpose of flight, yet they are capable of prehension as well, and in this respect are superior to the wings of birds, which are used for flying only. Their eyes are small, and ears large, because they are nocturnal animals, and they derive their ancient name (*Vespertilio*) from this circumstance—

lucemque perosæ

Nocte volant, seroque trahunt a vespere nomen.

They resemble man and the quadrumans in the structure of their placenta, and produce one or two at a birth, which are of very large size in comparison with the parent. They all possess clavicles, but the forearm does not admit of rotation, as this would interfere with the steadiness required for its use as a wing. They possess no cæcum at the commencement of the ascending colon.

The bats are divisible into two very natural groups—

1. The insectivorous bats.
2. The frugivorous bats.

These two groups are remarkably distinguished from each other, by characters suited to their different kinds of food, and the different habits required for procuring it. Thus, the intestinal canal in the frugivorous bats is seven times the length of the body, while in the insectivorous bats it is only twice that length. Also in the insectivorous bats the clavicle, and the portion of the sternum with which it articulates, are much more developed than in the frugivorous bats, who require a power of flight sufficient to carry them from tree to tree only, and are not required to follow the rapidly changing flight of insects pursued for food.

D. THE CARNIVORES.—*Incisor teeth, generally six in each jaw; molars uniformly enamelled, with acute uneven crowns; one or more of the hinder teeth tuberculate. Toes mostly cloven; thumb not separate from the other toes or fingers. Placenta deciduate, zonular.*

The Bengal Tiger, drawn from the life in Fig. 121, may be regarded as the type of the large Cats, which are the most highly organized of all the Carnivores.

These mammals live mostly on animal food, some exclusively ; a few of them eat fruits also, and other vegetable matters. Their



Fig. 121.

motions are rapid, and irritability great ; many possess uncommon muscular power. Their organs of sight and smell are peculiarly developed. They are divided into three groups, viz.—

a. *Digitigrade*.

b. *Plantigrade*.

c. *Pinnigrade*.

(a). *Digitigrade carnivores*, or walking on the toes without bringing the heel to the ground. Examples—*Otter, Dog, Cat*.

This important division includes the *Cats* proper, *Civets*, *Hyænas*, *Dogs*, *Otters*, *Skunks*, *Polecats*, and *Martens*.

Some of the *Digitigrade Carnivores* are provided with only one blunt molar behind the lacerator (*dent carnassier*), and form a very natural group, commonly called *vermin*—including the *Polecat*, *Weasel*, *Ferret*, *Ermine*, *Marten*, *Skunk*, and *Otter*. The *Otters*, as all know, are aquatic in their habits, and live upon fish and crustaceans ; they bring their prey ashore to be devoured, and when fish is scarce, they have been known to attack and destroy lambs. They inhabit sequestered nooks at the river side, and are nocturnal in their habits, like many other beasts of prey.

Another group of Digitigrade Carnivores, of which the Dog is the type, is characterized by having two blunt molars behind the lacerator of the upper jaw. This group includes Dogs, Wolves, Foxes, Civets, and Ichneumons. This latter animal was formerly worshipped in Egypt, on account of the services it rendered, by destroying the eggs of the crocodile; and it is still employed in India, as a domestic pet to destroy mice, rats, and small serpents. It readily attacks and kills the deadly *Cobra di capello*.* The Ichneumon has the pupil of the eye elongated transversely, like that of a goat. Dogs, Foxes, and Wolves, are closely related to each other, and some naturalists have regarded them as descended from a common ancestor; the fox is more remote from the dog and wolf than these are from each other, for the dog and wolf will breed together, while the fox and dog will not; their period of gestation is identical, viz. sixty-three days; the fox also differs from the dog and wolf in the form of the pupil of the eye, which in daylight closes into a vertical slit, like the pupil of a cat's eye. The Civets form a link between the cats and dogs; and like the cats, their tongue is rough, and their claws retracted whilst walking, so that they are always sharp.

The remaining digitigrade carnivores are distinguished by having no molar teeth behind the lacerator tooth of the lower jaw; this group contains the Cats proper and the Hyænas.

The Cats have five fingers and four toes, and claws retractile

* Aristotle, in his History of Animals (ix. 7), thus describes the manner in which the Ichneumon was supposed to destroy the asps in Egypt:—"The Egyptian Ichneumon, when it sees the snake called the asp, does not set upon it without summoning its companions to its aid; these plaster themselves with mud as a protection against its blows and bites, and they accomplish this by wetting themselves and then rolling on the ground."

The Ichneumon has improved since Aristotle wrote, and now attacks the *Cobra* without any such formalities; he watches the moment when the snake poises its head to strike, seizes him by the throat, cracks his neck, and sucks his blood.

or semi-retractile, and include the most active and largest of the Carnivores. The lion is the most powerful of the cats, and belongs to the Old World; it is now found in Africa and Asia only, but in former times it abounded in Europe, and so late as the time of Xerxes, these animals were so numerous as to attack the camels of his baggage trains. The lioness carries her young only three months, and has been known to produce two broods of four and five each, in a single year, in the Zoological Gardens of Dublin; the cubs come into the world marked with dark stripes, and spots like those of a leopard; both these kinds of markings disappear from the adult hide. The lion is said to prefer the flesh of the camel to that of all other animals, while the tiger is known to give a preference, like the leopard and crocodile, to the flesh of man himself. Notwithstanding all that has been said of the noble qualities of the lion, it must be confessed that he is a coward as compared with the tiger, and always attacks the smallest and weakest animal he can procure; the royal beast owes much of his high reputation to his imposing mane of long hair. He never attacks man without provocation, as the tiger will, who has been known in India to attack a file of horse soldiers on the march, and having snatched one from his saddle, to carry him off into the recesses of the jungle, without the possibility of rescue.

The Puma and Jaguar of the New World may be regarded as the representatives of the Lion and Tiger of the Old World.

The Hyæna occupies a position intermediate between the Dogs and Cats; its claws are not retractile, but resemble those of the dog, except that it possesses only four fingers, as well as four toes. The fore limbs of the Hyæna are so much larger than the hind limbs, in proportion, that the animal has the appearance of dragging the hind legs after him, which gives a singularly repulsive aspect to the gait of this animal. They are nocturnal in habit, frequenting caverns and old ruins, and are very voracious,

possessing jaws powerful enough to crack the shin bone of an ox, which is a feat beyond the powers of the lion or of the tiger.

(b.) *Plantigrade Carnivores*, or having the sole of the feet resting on the ground in walking. Examples—*Bear, Raccoon, Badger.*

The Virginian Bear, drawn in Fig. 122, may be taken as a type of the Plantigrades.

The animals included in this division of the carnivores are less carnivorous in their habits than the digitigrade carnivores, and many of them, as the Bear and Badger, are capable of living upon vegetable food, as honey, roots, biscuits, &c.; some of the bears never eat flesh by choice. The Bear has the same number and kinds of teeth as the Dog; the true molars are large and blunt, persistent, while the small pre-molars tend to disappear, after modes which vary among the several species. They have five fingers and five toes, and stand upon the hind legs in a manner more human than any ape is capable of doing; this peculiarity chiefly arises from the form of the thigh bone, which has been frequently mistaken for a human bone, by geologists not skilled in comparative anatomy. The white bear is the largest and fiercest of the plantigrade carnivores; it lives in the frozen regions of the north, and feeds on fishes, seals, and young whales; in confinement, however, it can be brought to feed largely, like other bears, on biscuits and other vegetable food, and it delights especially in a meal of omental fat.



Fig. 122.

(c). *Pinnigrade Carnivores*, or swimming by means of fin-like paddles. Examples—*Seal*, *Walrus*.

The Seal (*Phoca vitulina*), shown in Figs. 112, 123, and 124, may be taken as the type of the Pinnigrades.

These carnivores inhabit the water, and have four or six upper incisors ; lower incisors four or two ; the hands and



S. H. jun.

Fig. 123.

feet are palmate, pentadactylous ; the feet turned backwards and approximated to each other ; the fin-shaped hind

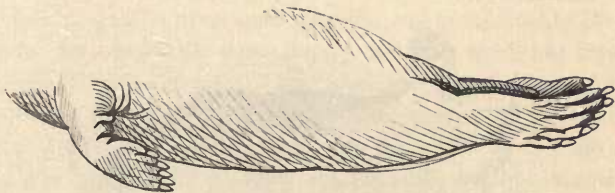


Fig. 124.

feet are blended into one screw-shaped organ with the flattened tail ; and the propulsion of the animal through the water is effected by the screw motion of the hind feet and tail, reversed at every stroke ; special arrangements of the muscles of the hind legs are made to suit this screwing action, which is so different from ordinary locomotion on land. The fore feet of the seal are not used in swimming,

towards which action they contribute as little as do the fins of a fish.

The Seals live in various seas, and are very numerous in species, especially in both the polar regions; they delight to sun themselves upon rocks, but their motions on land are awkward, resembling the vermicular motion of a caterpillar; they bark like a dog, and possess much intelligence, having a very large brain; the sense of touch is developed in an unusual manner, by means of the fifth pair of nerves, distributed to large bristles that surround the muzzle, which are supposed to guide the animal by touch under water; the nerves supplying these bristles are so large and important, that a blow of a stick upon the muzzle will kill a seal, from the nervous shock carried to the brain.

E. THE INSECTIVORES.—*Incisor teeth various in number, and not seldom different in the two jaws; no true canines in many species, false molars with double roots occupying their place; molar teeth with conical-pointed tubercles; feet plantigrade, often five-toed. Placenta deciduate, discoidal.*

The Mole, drawn in Fig. 125, may be regarded as a type of the Insectivores.

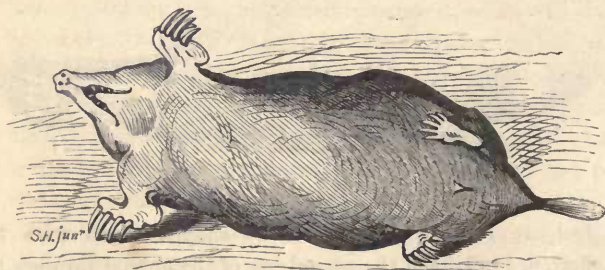


Fig 125.

The British Isles possess three examples of the Insectivores; viz., the Mole, the Hedgehog, and the Shrew, which render much service to the husbandman, by destroying insects and grubs,

the multiplication of which would prove destructive to his crops. The British farmer repays this kindness by accusing the Hedgehog of eating his apples, the Shrew of biting his horses, and the Mole of spoiling his land.

The Hedgehog is covered with spines instead of hairs, and has the muscles of the skin largely developed, by means of which he is able to roll himself into a ball, and so set his numerous enemies at defiance. This animal is endowed with extreme sensitiveness to moisture, and the following statement of Aristotle (*History of Animals*, ix. 7) is still regarded as correct:—“Respecting the sensitiveness of hedgehogs, it has been often observed, when the north and south winds are interchanged, that hedgehogs in the ground will change the openings of their burrows, and that those reared in the house, will change from wall to wall; and it is related that a man in Byzantium acquired the character of a weather prophet, by observing these habits of the hedgehog.”

The Mole, Fig. 125, lives a subterranean life, for which he is admirably adapted by his structure. The fore limbs are very short, and mounted on a scapular arch of strong construction; they are worked by muscles of unusual strength, and terminated by broad hands, furnished with short fingers, and long spade-like claws, turning slightly outwards. The hind legs are feeble, and the motions of the animal on the ground are as awkward as they are active beneath it. Its hearing is very acute, but its eyes are reduced to mere points, so that it can, probably, barely distinguish the day from the night. The Mole is remarkable for its domestic attachments, and for the care it takes in providing for its young. It feeds chiefly upon worms and grubs, and is fond of certain roots, such as the crocus, on which it feeds its young; for this reason, it is no favourite with gardeners.

The Shrew, or field mouse, has a general resemblance to the mouse, but is essentially a different animal; it readily takes the water, and swims and dives with ease; it is a most inoffensive

animal, and lives exclusively on worms and insects. Aristotle is answerable, to some extent, for the prejudice entertained against this innocent beast, for he says (*Hist. Animals*, viii. 23), “The bite of the shrew mouse is injurious to other animals, as well as to the horse; it causes sores, which are more severe if it is pregnant when it bites, for the sores then break; if they are not pregnant, the animal does not perish.” The *Shrew* is one of the smallest of mammals, measuring only $2\frac{1}{2}$ inches in length.

F. THE UNGULATES.—*Feet hoofed; unfit for grasping, and of low tactile sense; the limbs restricted in use to support of body and locomotion; molars with broad summits for grinding vegetable food. No clavicles. Placenta either diffuse, or arranged in cup-shaped masses (cotyledons).*

This important Order of herbivorous mammals is divided into two sub-orders, according as the number of the fingers is even or odd.

(a.) *Even-toed Ungulates have nineteen lumbodorsal vertebræ; horns, if any, in pairs; they are divided into the two groups—*

1. *Ruminants*, that chew the cud. Examples—*Deer, Camel, Giraffe.*
2. *Omnivores*, as the *Pig, Hippopotamus.*

1. *The Ruminants, feet bisulcate, with two toes insistent, ungulate, two supplementary hoofs in many. Molar teeth complex, upper incisors mostly none, lower eight, more rarely six; canines mostly none. Four, or three stomachs. Metacarpal and metatarsal bone single, bipartite below.*

This important sub-order of animals is of the greatest use to man, and has been known to him from time immemorial. Moses correctly distinguishes the Ruminants from the Omnivores, by stating that a true ruminant must both “chew the cud,” and “divide the hoof,” and he therefore excludes the Pig from this sub-family. Some ruminant animals have horns, and others have not; among those not provided with horns, the most important are, the Camel, and its representative in the New World, the Llama.

The Llamas are illustrated by Fig. 126, which shows the head of the Guanaco ; and Fig. 127, which shows the foot of the Llama proper.



Fig. 126.

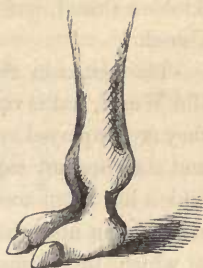


Fig. 127.

The Camel and Llama are distinguished from other ruminants, as well by their hoofs as by the possession of incisor teeth in the upper jaw ; these teeth arise from the inter-maxillary bone ; they are close to the canines, and agree with them in form. Their feet are callous beneath, with undivided sole, didactylous, without supplementary hoofs. The *Camelidæ* form a connecting link between the ruminants and the other ungulates, by having six incisors in the upper jaw, and by the fact, that their *placenta* is *diffuse*, and not composed of *cotyledons*, or cup-shaped masses. They have the upper lip cloven, and the neck very long.

The *Camel* derives its name from the Hebrew tongue ; it feeds on dry or prickly plants, and drinks seldom. They are rapid in their course, and bear large burdens, from 600 to 1000 lbs. ; hence they are of great service in the deserts which stretch from Arabia, through sub-central Africa, to the Atlantic Ocean, where no fresh plants cool the air, no fountain gives fertility, and the wind blowing in arid whirlpools, causes interminable oceans of sand

and dust. The Arabs have properly named this valuable animal "The ship of the desert." Within the last year, 1866, the Camel has been used in Australia, in an expedition across the deserts of that country, and has proved itself, as in Africa and the East, in every respect superior to the horse. There are two species known, distinguishable from each other by having one or two humps upon the back; that with one hump is called the Dromedary, or Arabian Camel, and that with two humps is called the Bactrian Camel.

The Llama in South America represents the Camel of the Old World, but is very inferior to the camel in strength and size; they are employed as carriers, but their usual load is only 150 lbs.; and they are not capable of the rapid motion of the Dromedary, which has often accomplished 100 miles a day for several days, with a man upon his back. There are several species known, of which the Llama proper, and the Vicuna, are highly prized for their wool.

The ruminants furnished with horns are so well known, that a minute description of them is quite unnecessary. The horned ruminants may be thus classified; ruminants having —

1. Horns always under the skin (*Giraffe*).
2. Horns permanent, hollow (*Cow*).
3. Horns deciduous, or antlers (*Deer*).

The Giraffe has two frontal horns in both sexes, conical and truncated, short, covered with hairy skin, and persistent; its neck is very long; the fore feet longer than the hind feet, like the Hyæna. The Giraffe is the tallest of mammals; when standing up, its height is 16 to 18 feet; its tongue is long, and possessed of great mobility, and is used by the animal to strip from trees the leaves on which it feeds, which are chiefly those of the Mimosæ. The Giraffe also grazes without kneeling, with the fore feet widely straddling; in its flight it gallops with the fore legs stiff, in rising and falling; at other times it has an ambling gait.

Its period of gestation is fourteen months, and the young is very large at birth. The Giraffe is a native of Nubia and Abyssinia, and is also found in South Africa. In its anatomical structure it is more closely related to the Deer than to the Antelope. The gigantic fossil ruminant, called *Sivatherium*, found on the flanks of the Himalayahs, is supposed to have been allied to the Giraffe.

The *hollow-horned ruminants* are provided in both sexes, or in the male only, with double horns, composed of a bony nucleus and a horny sheath persistent; there are accessory hoofs in many; no incisors in upper jaw, six incisors in lower; no upper canines; molars six in each jaw; or

$$\text{I. } \frac{0-0}{3-3} \quad \text{C. } \frac{0-0}{1-1} \quad \text{M. } \frac{6-6}{6-6}$$

The horns consist of a bony core, and a horny case covering the bone; the horny covering is produced by the surface of the core, and is composed of hairs concreted into a horny substance, of which a new ring is formed each year, as may be seen on examination of a cow's horn. In many of these animals the bony core is itself hollow, as in the Cow and Goat, but in others, as the Antelope, the bony core is solid; this, however, is but a small difference, and the whole group was justly regarded by Linnæus as one of the most natural in the Animal Kingdom. It may be divided into the four genera, *Antelope*, *Goat*, *Sheep*, *Ox*.

The Antelopes are most numerous in Africa, in the southern part of which they abound; many species present external resemblances to the Deer, others to the Goat, some to the Ox, and some even to the Ass; in all, the eyes are placed higher and more backward than in the Deer, and the base of the horns is mostly placed forward over the margin of the orbit of the eye, and the bones of the nose are usually very long.

The Goats have horns in both sexes, flat on the inside, curved, annulate, and often knotted; they live in troops in the mountains, and have very acute senses; the domestic goat has a sharp edge

at the inner side of the horn, which is irregularly incised, and sometimes very broad.

The Sheep was originally, when wild, an inhabitant of hilly countries, and therefore thrives well in high and dry regions; and is one of the most useful of the animals that man has tamed. The Sheep possess horns, in one or both sexes, wavyly striated, transverse at the base, turned backward, with the tip mostly again bent forward. There are many varieties, among which may be mentioned the merino sheep, celebrated for its fine wool; the Astracan sheep, noted for the curly fleece of the lambs; and the Iceland and Syrian sheep, remarkable for their four or six horns.

The Oxen have horns round either throughout, or towards the tip, turned outwards, incurved at the tip, ascending; and are distinguished, by having four teats, from the goat and sheep, which have only two. The varieties of oxen are geographically widely distributed, but it is remarkable that South America has produced no original wild species.

The common Ox may live to twenty or twenty-five years; and the period of gestation of the cow is 280 days; the calf is born with cutting teeth and three molars in each jaw on both sides. The varieties of the ox are fewer than of the sheep; among them may be mentioned, the *Zebu* of India, provided with a delicious hump upon his shoulders; the *Bison*, in which the horns are situated in front of the sharp line which divides the forehead from the descending part of the skull: the *Buffalo* has the horns directed outwards, and with a longitudinal projecting line; its native country is India, from whence it was introduced into Italy in the seventh century; lastly the *Musk ox*, inhabiting the sub-arctic regions of North America, has a hairy muzzle, the horns approach each other at the base, and then proceed outwards and downwards, the point turning up again nearly as in the *Gnu*, which is the wild ox of Southern Africa.

The last division of the *Ruminants* contains the *Deer*, the males

of which shed their horns each year ; many of them have canine teeth in the upper jaw.

The Sambur Deer (*Cervus Aristotelis*) of India, whose head and foot are shown in Figs. 128, 129, may be regarded as a type of this group of Ruminants.

The deers live principally in forests, both in the Old and New Worlds, and in very different climates ; from Africa only one* species is known, and not one from Australia. Most of them run with speed, and so lightly, that the beat of their feet upon the ground is not heard. The horns



Fig. 128.



Fig. 129.

of the deer are bony excrescences which are developed on cylindrical processes of the frontal bones called the *Rosestocks*. The rosestock is covered with skin and hair, and forms, when the animal is born, a bone distinct from the frontal bone ; with the rosestock of the true deer the horns of the giraffe correspond. The horns grow

* *Cervus Barbarus* is the only species peculiar to Africa. Besides this and the fallow deer, there is an Algerian variety of the stag (*Cervus Elaphus*).

each year from the rosetock very rapidly, so that in a few weeks they attain their full size ; the earthy part of some, as the *Cervus megaceros*, amounting to eighty lbs. At first they are covered by a woolly investment or skin, and afterwards the skin dies and falls from the horns in shreds. The horns are cast in the same season in which they grow. The females, with the exception of the reindeer, and perhaps the *Cervus megaceros*, have no horns. Among the most interesting varieties of the deer may be mentioned : the *Elk*, which is the largest living deer, and almost equals the horse in size ; it has large flat palmate horns, and is found in the northern parts of the Old and New Worlds ; the *Reindeer*, which inhabits the regions north of the district of the elk, and constitutes the chief wealth of the Laplanders, who by means of it, supply all their wants of clothing, food, and furniture ; the *Fallow* deer, which is spread by the influence of man over many countries, and is naturally wild in Italy, Spain, and North Africa : the *Red* deer is easily known by its rounded horns. One of the smallest species of deer is the *Muntjac* of Java and Sumatra ; it has large rosetocks and small horns, with canines in the upper jaw, projecting from the mouth in the male.

2. *The Omnivores.* The *even-toed ungulates* are divided, as already stated, into the *Ruminants* and the *Omnivores*, or as they might be named *ruminant* and *non-ruminant*. The non-ruminant even-toed ungulates, or omnivores, contain two divisions, the Pigs and the Hippopotamus, and they differ from all the odd-toed ungulates, in not having a third trochanter, or prominence, developed on the back of the femur,* the stomach, although not multiple, as in the ruminants, is complex, the cæcum is smaller, and the colon is spirally folded.

The Pigs have feet with the hoofs insistent, tetradactylous,

* This is a distinction more apparent than real, for the muscle to which the trochanter belongs is found in the Cow and Pig, as well as in the Rhinoceros, Horse, and others.

the hinder sometimes tridactylous; nose with snout truncate, moveable, prominent; tail short, or a tubercle in place of tail. In addition to the true hogs (*Sus*) this family contains the *Peccary* of America, and the *Wart hog* of Africa, which differ in some particulars from the common hog. The *Wild hog* lives in the forests of Asia and Europe, and is an exceedingly voracious and prolific animal, producing from ten to fourteen at a birth; near Upsala, a variety with a single hoof is found, as also in Hungary; and there are many varieties found in Mexico, the Moluccas, Japan, and other places, but not worthy of being regarded as distinct species.

The Hippopotamus has short tetradactylous feet, with short hoofs; body obese, covered with skin almost devoid of hair; it has the following dentition:—

$$\text{I. } \frac{2-2}{2-2} \quad \text{C. } \frac{1-1}{1-1} \quad \text{M. } \frac{6-6}{6-6}$$

the lower incisors are procumbent, horizontal; the canines large, worn obliquely into a very smooth surface at the back part; the molars are tuberculate and complex.

This River Horse, or Sea Cow, is a very heavy and sluggish animal, attaining a length of more than eleven feet; it resides by preference in rivers, and sometimes in the sea, and lives solely on plants, especially grasses. The Hippopotamus, which was formerly met with in Egypt, is not now found farther north than Abyssinia, but further south throughout the whole of Africa. Its stomach, though not multiple, contains three divisions, and it has an intestinal canal twelve times the length of the body, not furnished with a cæcum. The feet, with its four short-hoofed toes, and broad palm, are admirably adapted to the habits of the animal, which delights in wading about in the soft mud of shallow lakes and rivers, where it spends the greater part of the day.

(b.) *Odd-toed Ungulates.* *Dorsolumbar vertebræ more than nineteen in number; horns, when any, never in pairs.* It is to be ob-

served that in counting the number of digits, in the odd-toed Ungulates, we are to be guided by the toes of the hind feet only. Thus, the Tapir has three toes only on the hind feet, and, therefore, is always classed with the three-toed ungulates, although it never fails to have four fingers on the fore feet. The odd-toed ungulates are divided into—

1. *Solidungulates*; one-toed; example, the *Horse*.
2. *Multungulates*; three-toed; example, the *Tapir* and *Rhinoceros*.
3. *Proboscidiens*; five-toed; with proboscis and tusks from one or both jaws; example, the *Elephant*.

1. The *Solidungulates* are represented by the Horse and Ass, which possess feet with a single perfect toe, covered by a broad hoof, without supplementary hoofs; incisors in a continuous series in both jaws; molar teeth complex; two inguinal teats. Dental formula—

$$I. \frac{3-3}{3-3}; C. \frac{1-1}{1-1} \text{ or none; } M. \frac{6-6}{6-6}$$

All the species of horse belong to the Old World, and are at home on the wide mountain plains of Asia and Africa; they live together in troops, are very swift, and feed chiefly on grasses; their intestinal canal is wide and long; they have a simple stomach, a large cæcum, and no gall bladder.

The domestic Horse, like the Camel, is no longer met with in its wild state, but has returned to that condition in the steppes of Asia, and in the plains of South America. The horse lives about thirty years, but sometimes over forty years; they carry their young eleven months, and contain many varieties more or less prized and cultivated by man.

The Ass differs from the horse by having his tail hairy at the end only, while that of the horse is hairy throughout; he has also a black cross upon his shoulders, and long ears. The wild ass lives in large troops in Tartary, and migrates in winter to more southern regions.

There are three striped horses found in South Africa, which are regarded as being more closely related to the ass than to the horse; these are, the *Zebra*, the *Quagga*, and the *Onagga*.

The *Zebra*, very like the ass in build, is unlike him in disposition, being the most intractable of all the solidungulates; his skin is beautifully soft, and marked with brown and yellow stripes, which in the female become black and white.

The *Quagga* resembles the horse more than the ass; it is brown with black stripes, the belly and legs white; they are very shy, and live together in troops of eighty to a hundred; they are called *khona khona* by the Hottentots.

The *Onagga*, or mountain horse, is smaller than the Ass, and is striped black and white like the *Zebra*, with white legs.

2. The *Multungulates* have three toes on the hind feet, and generally three fingers, but sometimes four; the lumbodorsal vertebræ are never fewer than twenty-two; the femur possesses a third trochanter, and the middle toe is large and symmetrical. If the species be horned, the horn (one or two) is placed in the middle line of the head; the stomach is simple, and the cæcum large and sacculated.

The Rhinoceros is so called, from having one or two horns upon its nose in the middle line; these horns are formed altogether of compacted tubes, without any bony core; it has three toes on all the feet. They are heavy animals, with a long head and short tail; they frequent marshy places, and live on herbs and branches of trees. The *villi* of the small intestine are very large; and the intestinal canal is eight times the length of the body; the large intestine forms several large sacks at its commencement.

The Asiatic species of rhinoceros have incisor teeth in both jaws, while the African rhinoceros has the incisor teeth of the lower jaw small and latent, and those of the upper jaw are either none, or disappear early. The African rhinoceros is dangerous to travellers by night, and enjoys a very acute sense of hearing and

of smell. The rhinoceros possesses a distinct muscle attached to the third trochanter.

The *Tapirs* have four fingers and three toes; the nose is produced into a small moveable proboscis; the American species are found in South America, chiefly in the neighbourhood of the east coast, in woods and moist places on the banks of rivers; and some of them attain a length of six feet. The Asiatic species are confined to the peninsula of Malacca, and the island of Sumatra. The fossil animals of the Parisian Tertiary beds described by Cuvier under the name of *Palæotherium*, had three toes on all the feet, and were closely related to the Tapirs. The fossils described by him as *Anoplotherium*, were more nearly related to the Pigs, and were two-toed Ungulates. The *Tapirus giganteus* of Cuvier, more recently called *Dinotherium*, had molars resembling the Tapir, with two large tusks in the lower jaw directed downwards; it is now believed to have been a Marsupial mammal.

3. *The Proboscidians* are represented by the Elephant, of which there are only two species living.

They have two incisor teeth in the upper jaw, exsert, large; no canines; molars large, with crown elongate; five fingers, and the same number of toes; nose elongated into a long prehensile proboscis; two pectoral teats. The fossil *Mastodons* belonged to the Proboscidians, and are distinguished from the Elephant by the crowns of their molars having nipple-shaped tubercles arranged in pairs. The Elephant lives in forests, in the tropical regions of Asia and Africa, mostly in troops; few of them exceed ten feet in height; they live to a great age—upwards of 100 years; their gestation lasts twenty or twenty-one months, and the young elephant sucks with the mouth and not with the trunk; they are very docile, and seem to have been educated by the ancients more perfectly than in modern times. The Indian elephant has an oblong head, a concave forehead, ears of middling size, and four nails on the hind feet; the bands of enamel in the molar teeth are narrow, parallel, and sinuous; it is found native in India and Ceylon, but

not in Java. There is a variety of the Indian elephant found in Sumatra and Borneo, in which the plates of enamel are thicker and less numerous than in the Indian species; it has also twenty pair of ribs instead of nineteen pair.

The African elephant has a round head, a convex forehead, large flattened ears with semicircular flaps, and only three nails on his hind feet; it has rhomboidal bands of enamel; it is fiercer* than the Indian elephant, its tusks are longer, and the female possesses them as well as the male.

G. THE RODENTS.—*Incisor teeth in both jaws, two, large, incurved, destitute of roots; canines none; molars remote from incisors by an interval; mostly few, rarely exceeding four in each side of both jaws. Feet unguiculate, mostly pentadactylous. Placenta deciduate, discoidal.*

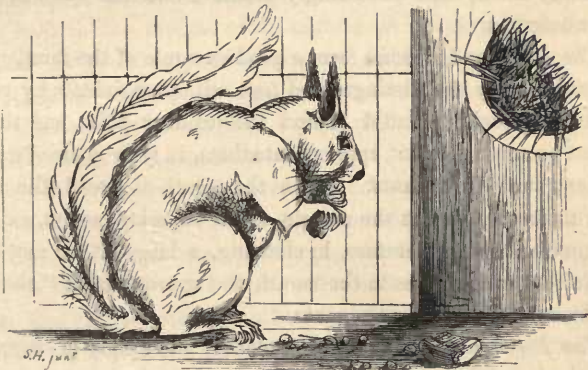


Fig. 130.

* The revengeful ferocity, characteristic of the African Elephants, is said to have been used by the soldiers of Hannibal as a means of inducing them to cross the Rhone. "Elephantorum trajiciendorum varia consilia fuisse credo: certè variata memoria actæ rei. Quidam, congregatis ad ripam elephantis, tradunt, ferocissimum ex iis irritatum ab rectore suo, quum refugientem in aquam nantem sequeretur traxisse gregem, ut quemque timentem altitudinem destituerat vadum, impetu ipso fluminis in alteram ripam rapiente."—*Liv. xxi. 28.*

The Rodents are well represented by the *Squirrel*, shown in Fig. 130.

The incisor teeth are covered by a plate of enamel, on the anterior surface only, which in many species is coloured yellow or ruddy brown; not only the enamel, but the anterior portion of the dentine, is harder than the back part of the teeth; hence a greater wearing down of these teeth is effected at the back part by use, and their crowns acquire a chisel shape, with a surface declining from the sharp front margin backward; the condyles of the jaws are longitudinal and not transverse, as in the Carnivores, and allow of the motion of the lower jaw backwards and forwards. The Rodents live principally on vegetable food, often on the hard parts of plants, as bark of trees, roots, &c. They are commonly small, and exceedingly prolific; and the species are very numerous.

The *Hares* and *Rabbits* form a good example of the family of Rodents. They are distinguished from all other rodents by two small upper incisors placed behind the ordinary pair; and they present peculiarities that approximate them, in their mode of mastication, to the ruminants. When the mouth is closed, the inferior molars lie within the margin of the superior molars, as in the ruminants, and therefore, in chewing, a large lateral motion is required, which gives to the mouth the appearance of "chewing the cud," as in the ruminants.

The *Porcupines* belong to the rodents; their body is covered with rigid, pointed spines, as is well known; fingers four, toes generally five, but the hand is also provided with a very small thumb, resembling a wart. They are found in both hemispheres, and, with the exception of a single species, in warm countries; they possess clavicles attached to the sternum, but not to the scapula; and feed on young shoots of trees, bark, and fruits.

The *Beavers* are aquatic rodents, having the toes of the hind foot joined by membrane, and the second toe provided with two oblique claws; the tail is depressed and scaly. They attain

a length of three feet, without the tail, and live solitary in Europe and North of Asia, but form colonies in the rivers of North America; the social beavers are able to fell large trunks of trees by means of their powerful incisors, and so form dams across the streams on which they build their nests or domes.

One-third of the known mammals are Rodents, and of the known Rodents, one half are Rats and Mice. These well known types have four fingers and a wart-like thumb, and five toes; with distinct clavicles, and long tail. Of the house rat, there are several well known varieties. The Black rat has a tail the same length as the body, and a bright glossy fur; the white rat is a sub-variety of this kind. The Norway rat is brownish grey, and has a tail shorter than the body. This variety, which is now the common house rat of these countries, first penetrated from the East in the middle of the eighteenth century, and has expelled the black rat by its superior fecundity, and not by its strength or courage, although it is larger than the black rat.*

The largest known Rat is that of Bengal and Coromandel, which attains a length of two feet.

Of the Rodents, altogether, there are about 700 species known, and of these, upwards of 300 are Rats; of the remaining rodents, nearly one-half, or more than 150, are *Squirrels*. These well-known animals live in trees, and feed chiefly on nuts, small birds' eggs, and beetles, and they hibernate in cold weather more or less, and frequently in colder countries become white in winter. Some of them, called flying squirrels, have on each side of the body a prolongation of the skin extending between the fore and hind limbs, like the flying cats (allied to Monkeys) of Madagascar, which forms a sort of parachute, by the aid of which these animals can take long leaps downwards; these are found in Poland, Russia, and North America.

* I have several times tried the Black and Norway rat in single combat, and always with the result, that the Black rat killed quickly the Norway rat, and then ate his brains.

H. THE MUTILATES OR CETACEANS.—*Anterior limb changed into fins ; posterior limbs wanting ; tail horizontal, flat, continuous with trunk ; no external ears. Placenta indeciduate, diffuse.*

The Cetaceans or Whales are divided into two groups, the *carnivorous* cetaceans, and the *herbivorous* cetaceans ; and are well illustrated by the common Porpoise, drawn in Fig. 131.

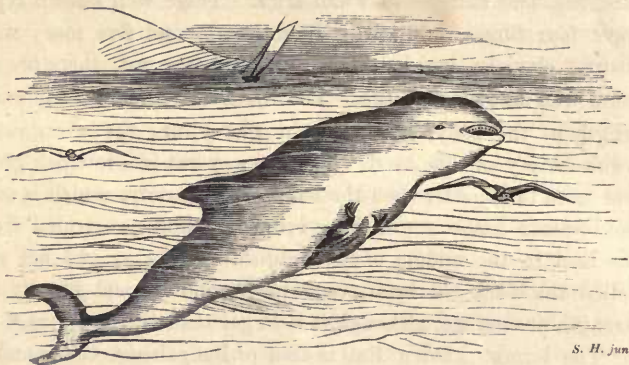


Fig. 131.

- (a). *The Carnivorous Cetaceans* have blowholes on the top of the head leading into the nostrils ; *teats inguinal ; teeth conical*, never molars with flat crowns ; body destitute of hair. The *Carnivorous* or true Cetaceans live almost all in the sea exclusively, and the largest animals in nature are found among them ; they are provided, like the pinnigrade Carnivores, with a thick layer of fat under the skin, to protect them from the cold water. It is a mistake to suppose that these animals spout water from their blowholes ; they commence to expire air before reaching the surface, in order to be ready to inspire it again with as little delay as possible above the water ; the central column of air may be seen in the spout, surrounded by a clear tube of water drawn up with it by friction, and this appearance has led to the mistake that these animals spout water.

The *Whalebone* whale is so called from its having trans-

verse horny plates adherent to the upper jaw in place of teeth; these plates constitute the whalebone of commerce, and are used as filters by the whale to separate from the sea water, the small sea jellies and mollusks that constitute its chief food. In some of these whales the head is very large—sometimes one-third of the whole length. They have two blowholes. The *Greenland*, or common whale, attains a length of sixty feet, and has more than 300 plates of whalebone on each side of the mouth. The *Rorquals* are distinguished from the other whales, by having a fin upon the back, and although larger occasionally than the Greenland whale, are comparatively useless, for their whalebone is worthless, and they have much less blubber than the common whale; some of the *Rorquals* have been found 100 feet in length. The *Spermaceti* whale is distinguished from the Greenland whale by its single blowhole, by its lower jaw furnished with a row of large conical teeth, and by its upper jaw containing a few teeth concealed under the gums. It attains nearly the size of the Greenland whale, and is met with in various seas. The *spermaceti* consists of a fatty substance contained in special cavities of the head, at the upper part of the skull; and in the intestines is found the grey amber, a sort of cholesterine, which is used as a perfume, since, when burnt, it emits an agreeable smell; this *ambra grisea* is sometimes found drifting on the sea in warm countries, and is thrown up on the coasts. The sperm whales live upon cephalopods, and are hunted chiefly in the North Pacific, between the Sandwich Islands and Behring's Strait. The *Narwhal*, or sea unicorn, has two horizontal canine teeth in the upper jaw, that of the left side being, in the male, very long, straight, awl-shaped, and spirally grooved, while that of the right side is undeveloped. It often attains a length of thirteen feet, independent of the tusk, which may be ten feet more. The *Dolphins* and *Porpoises* have conical

vertical teeth, numerous in both jaws, and some of them attain a length of twenty-eight feet, but most of them do not exceed ten feet; they are found in all seas, and will ascend rivers in brackish water; they are very voracious, and swim with great speed.

- (b.) *The Herbivorous Cetaceans.* Nostrils opening in the upper lip at the anterior part of the head; *molar teeth with flat crowns*, or a horny plate instead of teeth in both jaws; *teats pectoral*. These cetaceans were formerly placed in the neighbourhood of the seals, and one of them, the *Manatee*, was even classed in the same genus with the *Walrus*. They are, however, true *Mutulates*, and not pinnigrade, for they are entirely destitute of hind limbs. The intestinal canal is very long—sometimes twenty times the length of the body—as in Steller's Sea Cow; the stomach has two blind appendages at its pyloric end, which is separated from the cardiac end by a constriction, and the cardiac portion of the stomach is itself a blind sack, lined with many follicles. Although the hind limbs are wanting, there are always present traces of the pelvic arch. They feed upon seaweeds, and keep near the shore and mouths of rivers.

There are three kinds of Herbivorous Cetaceans known.

1. *Steller's Sea Cow.* This remarkable animal formerly lived on the coast of Kamschatka, at Behring's Island, and attained a length of twenty-four feet; it was discovered and described by Steller in Behring's second voyage. This animal has not been seen since 1768, and at the time of its discovery at Behring's Island had already become very scarce.

2. The *Dugong* of the Malays occurs in the Indian Ocean and in the Red Sea; it sometimes attains a length of twenty feet.

3. The *Manatees* inhabit the warm regions of the Atlantic, on the west coast of Africa, and east coast of South America, frequenting the mouths of the great rivers of these countries. Like the *Dugong*, they are used as food, and considered very palatable;

they attain a length of more than fifteen feet. These are the animals that have given rise to the fables of the *Mermaid*; from their pectoral mammæ, and habit of holding the young between their hand-like flippers; their face is not so human as those of the seal and walrus, but is sufficiently so to apologise for the tales of the Arabian sailors.

I. THE EDENTATES. *Incisor and canine teeth almost always wanting, and sometimes the molars also; toes provided with large curved, compressed claws; sacrum formed of few vertebræ; teeth, when present, without enamel, growing as they are worn down.*

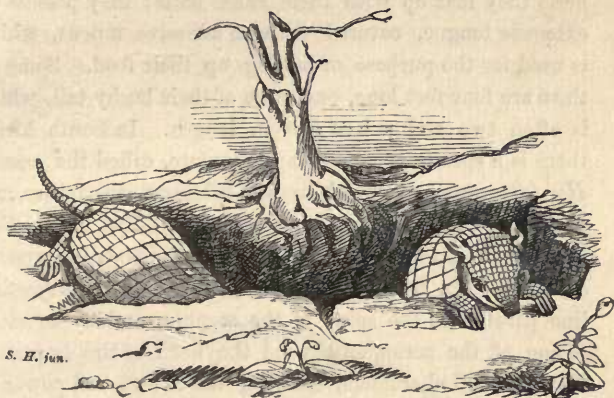


Fig. 132.

I have selected, to illustrate the Edentates, a pair of Armadillos, engaged in the congenial occupation of searching a grave (Fig. 132). All the species of this remarkable and undeveloped Order live in the warmest countries of the earth; no animal belonging to it is found in Europe.

The Edentates are divided into two distinct sub-orders viz. the *burrowing* Edentates, and the *tardigrade* Edentates.

(a.) *The burrowing Edentates* have the head produced to form a long narrow snout; the feet are short, the hinder being the

longer; claws curved and adapted to digging in the ground. These animals feed upon insects, some exclusively, while others feed upon offal in addition; a few of them climb trees, in which they are assisted by a prehensile tail; most of them, however, live upon the ground, or under ground in holes that they have dug.

These animals are represented in the Old World by the *Scaly Anteater (Manis)*, of Guinea and Ceylon; and by the *Anteaters* of South America, especially of Brazil and Guiana. These creatures live in the forests and feed on ants, whose nests they tear up with their large nails; they possess an extensile tongue, covered with an adhesive mucus, which is used for the purpose of licking up their food. Some of them are four feet long, exclusive of their bushy tail, which is often two and a half feet in length. In South Africa there is a species of burrowing Edentate, called the *ground Hog (Orycteropus)*, which lives in subterranean cavities, and attains a length of upwards of four feet. The *Armadilloes* of South America are distinguished by the peculiar breadth of the first rib, by well-developed clavicles, by a projecting line parallel to the spine of the scapula, and by an elongation of the acromion beyond the head of the humerus. These are all characters, showing the extent and power of the muscles employed in digging; they can bury themselves in the ground when pursued, and tunnel through it as fast as a man can follow them with a spade.

- (b.) *The Tardigrade Edentates* have the head truncated anteriorly; the legs, especially the fore legs, very long; and the claws compressed and incurved. These animals, popularly called *Sloths*, live in South America, in the forests, and feed upon the leaves of trees, from which they hang suspended by their curved claws. The Edentates are especially remarkable for the gigantic species belonging to this family that lived in South America before the creation of man; among the most

remarkable of which may be named, the *Megatherium*, a fossil Sloth that exceeded the Rhinoceros in bulk; and the *Glyptodon*, a fossil Armadillo, upwards of nine feet in length.

The *non-placental Mammals* are divided into two great groups, which probably differ as much from each other as they both do from the *placental Mammals*. These divisions are—

II. Non-Placental Mammals.

K. Didelphs or Marsupials.

L. Ornithodelphs or Monotremes.

K. DIDELEPHS OR MARSUPIALS. These animals were so named by Linnæus, because they are provided with an abdominal bag (*marsupium*), in which the immature young are placed by the mother after their birth, and this bag performs the part of a second womb (*διδελφύς*); the teats are inguinal, and open into the marsupium, which is supported by two marsupial bones turning on the pubic bones as hinges, and provided with muscles to raise and lower them as occasion requires.

The marsupial bones, *m m*, are shown in Fig. 133, which represents the skeleton of the Virginian Opossum.

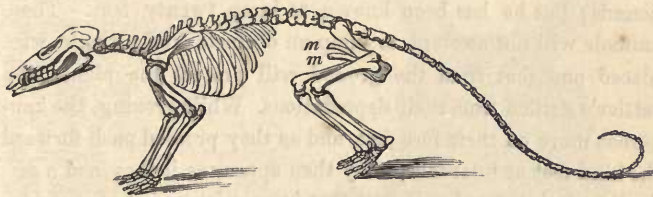


Fig. 133.

The marsupial bones, applied in the Didelphs to so useful a purpose, are found, also, in the lower vertebrates, as in the Alligator, Fig. 113, *m*; in these animals the only use of these bones is to support the guts, and to serve as an origin for the attachment of muscles that act upon the thigh bone.

The Marsupials may be divided into groups, more or less re-

sembling the subdivisions of the Placental Mammals; such as *carnivorous, rodent, insectivorous, herbivorous, &c.* The most remarkable of all the Marsupials are the *Kangaroos*, or Jumping Marsupials; these animals are herbivorous, and have six incisors in the upper jaw, which work against two incisors in the lower jaw, which are placed almost horizontally, and are worked backwards and forwards by powerful muscles (*pterygoid*), so as to form a most efficient cutting shears. Their hands and arms are small, but endowed with a great variety of motions, as well as their five fingers; and, as might be expected from the perfection of the hand, they are also provided with a very perfect clavicle. They are found in the Eastern part of Australia, and live on grasses and leaves; they may be regarded as representing the placental ruminants and hares. It is a great mistake to suppose that these animals perform their surprising jumps by placing the tail upon the ground to aid the hind legs; the tail is thus used only in the quiet motions of the animal, and aids the jump by being suddenly straightened, like a fishing rod, at the moment of the spring. The usual jump of the *Giant Kangaroo*, which is four feet in height, is fourteen feet effected for miles in successive bounds; but he has been known to jump twenty feet. These animals will not attempt to jump an obstacle, and a single wire placed one foot from the ground will protect the plants of a settler's garden from their depredations. While grazing, the kangaroos move on their fore feet, and as they proceed push forward the hind feet at intervals; they then appear as if they had a difficult and obstructed gait, but that impression vanishes as soon as they are pursued; they then move by wide leaps on their powerful hind legs; lashing the air vertically with heavy strokes of their muscular tails.

The general characters of the head and hinder quarters of the kangaroos are shown in Figs. 134, 135, which represent one of the smaller species of Wallaby.

The *Opossums* of America, and *Phalangers* of Australia, pre-

sent many features in common, and, possibly, may be considered to represent the Quadrumans among the placental mam-



Fig. 134.

mals; they have five toes, the hallux being opposable, and not furnished with a claw; they are all fruit-eaters (*carpophagous*), and adapted for climbing trees; they will also eat insects and small reptiles, when fruit is scarce. The Opossums are peculiar to America, while the Phalangiers are met with in the Indian Archipelago, New Guinea, and Australia: some of the Phalangiers have expansions of the skin, like the flying squirrel, and resemble the Lemurs in many respects.



Fig. 135.

Among the Marsupials that belong to the Carnivorous group may be mentioned the *Native Tiger* (*Thylacinus*), and the *Native Devil* (*Dasyurus ursinus*), remarkable for their great strength and ferocity as compared with their size. The Native Tiger resembles a Wolf in size, and is marked with stripes like a Zebra; it is four feet in length, and preys upon Kangaroos and Sheep. The Native Devil is much smaller, but even more courageous than the Native Tiger, and it is said to be able to attack and kill a bulldog with ease; it is brown with white spots.

L. ORNITHODELPHS OR MONOTREMES. *In these Animals, as in Birds, the cloaca receives the outlets of the intestine and of the urethro-genital organs; like the Birds, they have two clavicles, one coracoidal and the other furcular. The feet are short, and pentadactylous.* There are only two animals known belonging to this very remarkable group of mammals, which in certain characters resembles reptiles and birds. These animals are—

a. The Water Mole, or Duckbill, (*Ornithorhynchus paradoxus*).

b. The Porcupine Anteater (*Echidna hystrix*).

(a.) *The Water Mole, or Duckbill*, has eight horny teeth $\frac{2-2}{2-2}$,

flat, without fangs, composed of perpendicular horny tubules. the anterior narrow and long, and the posterior oval: snout depressed, resembling the bill of a duck. The Water moles live in the rivers and lakes of Australia and Van Dieman's Land; they dive and swim like water birds, and secure their prey while swimming, with their bill, as ducks do; they feed on worms and insects, and dig holes of twenty feet or more in length, which have a double entrance—one close above the water, and another below the water, and ending in a large space covered with rushes or other dry materials.

(b.) *The Porcupine Anteater* is well shown in Fig. 136, which represents a favourite attitude of this remarkable animal. The Porcupine Anteater has no teeth; its snout is awl-shaped with small gape; tongue long, round, exsertile, body co-

vered with hairs and spines; long claws. These animals burrow under ground, live on ants and other insects and grubs, and, like the Duckbill, are nocturnal in their habits. It is remarkable that the brain of the *Echidna* has convolutions, while that of the *Ornithorhynchus* is devoid of them.



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4. **Birds.** The second great division of the Vertebrates consists of Birds, which are vertebrate, warm-blooded, oviparous

Fig. 136.

animals that breathe by lungs; their heart consists, like that of mammals, of a left and right side, each provided with an auricle and a ventricle; their bill projects forward and is unprovided with teeth; the anterior limbs are changed into wings.

A. *Skeleton.*—The skeleton of birds presents many peculiarities, caused by its adaptation to the purpose of flight, as the usual mode of locomotion. In Fig. 113 I have shown the pelvic arch of the Alligator, which, like that of the Kangaroo, is regarded as typical of the greatest perfection in the structure of the hind limb; in Fig. 137 is shown the scapular arch of a bird, so constructed as to give the most fixed support possible to the wings. The sternum, *st.*, in all birds except those related to the Ostrich, is provided with a deep keel, that serves for the attachment of the powerful pectoral muscles that depress the wings

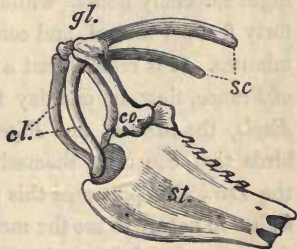


Fig. 137.

in the act of flying. The head of the wing bone (*humerus*) plays in the cavity *gl.*, formed, at each side, as in the pelvis of the crocodile, by three bones :—

sc. scapula.

co. coracoid.

cl. clavicle or furcular.

The *coracoid* bones, as in the reptiles, articulate with the side of the sternum, while the clavicles are generally free from the sternum, but fused into each other in front of it, forming the bone called the *furcular* bone of the bird.

The arrangement just described, by which the scapular arch is provided with two clavicles, gives a solidity to the centre of motion of the wing of the bird, quite comparable with the solidity given by the pelvic arch to the centre of motion of the hind limbs of mammals. The elbow of the bird's wing also is provided with an *armpan*, like the kneepan or patella of the hind leg.

The rapidity of the flight of a bird depends chiefly on its length of wing, and not upon its breadth; while its power of raising itself vertically in the air depends chiefly on the breadth of wing. The *Falcon* and *Swallow* are good examples of long narrow-winged birds, and neither of them can ascend vertically in the air without wheeling. These birds are known to fly at the rate of sixty feet per second, and to keep up this rate of flight for many hours, while the speed of the race horse is only forty feet per second, and cannot be maintained longer than a few minutes. It is related that a falcon, belonging to King Henry II. of France, flew in one day from Fontainebleau to Malta. The *Eagle*, the *Merlin*, and *Pigeon*, form examples of broad-winged birds that can raise themselves rapidly in a vertical direction; the *Lark* also possesses this power, and it is one of the prettiest sights in nature to see the merlin attack the lark, the pursuer and the pursued striving each to surmount the other in the air, victory always declaring itself in favour of the bird that can defeat its antagonist in the gymnastic feat of ascending vertically without wheeling.

B. Nervous System.—The nervous system in birds, both cerebrospinal and ganglionic, presents a general resemblance to that of mammals; the weight of the brain exceeds that of the spinal cord, and although it is destitute of convolutions, its different portions are united together, and do not form separate masses, as in lower classes of vertebrates. The brain is relatively larger than that of most reptiles and of all fishes, and it fills the entire cavity of the skull. Its proportion to the weight of the body in several birds, is—

In the Sparrow,	1 : 25
„ Chaffinch,	1 : 22
„ Goose,	1 : 300
„ Cassowary,	1 : 835

These figures, as well as those given for the mammals, p. 197, prove, in a general way, that size of brain is relatively greater in the smaller animals.

A narrow canal runs through the middle of the spinal cord, throughout its length; and the cord itself widens very sensibly at the points, where the *plexuses* are given off that supply the wings and legs; the canal of the spinal cord expands at its termination in a sack which is filled with a watery fluid.

C. Respiration.—There are two lungs present in birds, as may be seen at *ll*, Fig. 138, which represents the viscera of the Black Swan of Australia. These lie at the back of the chest, and do not cover the heart in front (*h*); they are not divided into lobes. The bronchial tubes are short, as compared with



Fig. 138.

S. H. Jun.

the windpipe, and penetrate the upper part of the lungs in front, they are perforated by several large apertures which lead into tubes, the extremities of which open into a remarkable system of air-sacks, situated partly in the chest, and partly in the belly, and whose office it is to conduct air into the hollow bones. The wing-bones, the sternum, and the cranium, are those most commonly found containing air cells; and it has been observed, that birds with a broken wing can carry on respiration by means of the cells opened to the air in the fractured extremity of the wing bone, when the ordinary passage of the windpipe is closed by compression. The air contained in these bone cells serves to diminish the weight of the bones, and also acts as a supplementary reservoir of air for the use of the lungs.

D. *Circulation.*—The circulation of the blood in birds, as might be expected from their high temperature and active habits, is as perfect as in the mammals. The heart of both is double, the right side being devoted to the pulmonary system, and containing venous blood (marked dark in Fig. 139); and the left side being devoted to the circulation of arterial blood through the entire body (marked light in Fig. 139). In Fig. 138 the heart is shown at *h*, and the great aorta having left the heart, divides at once into two arteries, *a* and *b*; the right branch, *a*, corresponds to the aorta of mammals; and the left branch, *b*, is the left sub-clavian artery.

There is a peculiarity in the heart of birds, which is common to them with the elephant and rodents; viz., the blood is brought back to the right side of the heart from the anterior part of the body by two veins (*venæ cavæ superiores*) instead of one. Many birds have a mean temperature of 110° , while that of man and other mammals is only 100° ; this arises from the



Fig. 139.

more perfect system of oxidation provided for birds, by the addition of air cells to their lungs. The chief difference between the heart of birds and the heart of mammals is to be found in the so called *tricuspid* valve, separating the right auricle from the right ventricle; this valve in birds is *not* tricuspid, but is formed of a single thick muscular septum, of a triangular form.

E. *Digestion*.—Birds, like mammals, are furnished with salivary glands, but as they have no teeth, the mixture of saliva with the food is much less complete than in mammals. This deficiency in mastication is supplied in birds, and in some reptiles also, by a remarkable developement of the pyloric end of the stomach into a muscular bag, called the *gizzard*, which is furnished with a horny rough inside coating, sufficient, with the aid of gravel swallowed instinctively by the bird, to effect the complete mastication of the most refractory food. The stomach of the Black Swan is shown in Fig. 140. The Œsophagus, *æs.*, lined with longitudinal wrinkles, leads into the *proventricle*, or crop, *c*, the inner surface of which is dotted, like a strawberry, with the circular mouths of the small blind sacks, that pour out the secretion of the gastric juice; the food macerated by the gastric juice in the proventricle is passed on between the horny grinders (*a, a*), urged together by two powerful muscles, the tendon of one of which is shown, divided. The *duodenum*, *d*, opens behind one of the grinding surfaces not far from the aperture leading into the gizzard from the proventricle. The gizzard is shown in its natural rela-

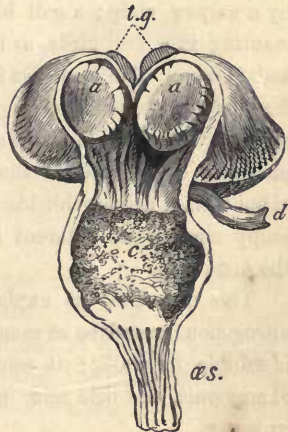


Fig. 140.

tions to the other viscera, especially the liver and gall bladder, in Fig. 138, where also one of the gizzard muscles is fully shown,

rendered a two-bellied, or digastric muscle, by the occurrence of its tendon in the middle. The intestines are relatively longer than in reptiles and fishes, but shorter than in mammals; the usual length is from three to five times that of the body. At the junction of the small and large intestines two long *cæca* are generally found, which are singularly long in the *Ducks*, and singularly short in the *Falcons*; while the *Hérons* have only one *cæcum*. The *rectum* terminates, by a muscular ring, or sphincter, not externally, but in a bladder-like expansion called the *cloaca*, which opens externally by a transverse slit, as in reptiles, and receives the excretions of the kidneys and genital viscera, as well as those of the intestinal canal. This is the peculiarity already noticed in the lowest forms of mammalian life—the *Monotremes*.

F. *The Liver, Pancreas, and Kidneys*.—The *liver* in birds is large, sometimes forming from $\frac{1}{20}$ th to $\frac{1}{10}$ th of the weight of the whole body; it is generally divided into two lobes connected only by a narrow strip; a gall bladder is commonly present, but is wanting in a few birds, as the *Ostrich*, the *Pigeon*, the *Parrot*, and *Toucan*. The *pancreas* is large, and is usually divided into from two to six lobes, each provided with its duct. In but few birds is only one duct present. The *kidneys* are long, and placed in depressions of the iliac bones; but they are not provided with a urinary bladder, and their secretion forms a white pulpy mass, quite different from the watery urine excreted by the mammals.

This difference is explained by the fact, that while the nitrogenous excretion of mammals consists chiefly of urea, which is soluble in water; it consists in birds, principally, of urate of ammonia, and uric acid, neither of which is readily dissolved in water.

5. **Classification of Birds**.—Birds are divided by naturalists into the following seven orders:—

- A. Raptorial Birds.
- B. Passerine Birds.
- C. Climbing Birds.
- D. Gallinaceous Birds.
- E. Running Birds.
- F. Wading Birds.
- G. Swimming Birds.

A. *Raptorial Birds*.—Bill, hooked, compressed, waxy at base, with open nostrils; feet strong, toes padded beneath, scaly, with hallux large, posterior claws long, strong, and curved; primary wing-feathers ten; tail with twelve to fourteen feathers. The Raptorial birds, or *Birds of prey*, are readily distinguished from all others by the foregoing characters, and by their general appearance and habits; they are divided, according to their habits, into *diurnal* and *nocturnal*.

The *diurnal Raptorial*s include *Eagles*, *Falcons*, and *Vultures*; of which the first two seek living prey, while the third content themselves with carrion.

The character of the head in the *diurnal Raptorial*s is remarkable, even in the young, as may be seen from Fig. 141, which represents the head of the female Condor Vulture at eight months old.



S. H. jun.

Fig. 141.

The *nocturnal Raptorial*s include the *Owls*, one of the most natural and well-defined of all the families of birds. These seek their prey by twilight and moonlight; it consists of small mammals, of sleeping birds, and of large insects, and frogs. The *nocturnal Raptorial*s differ, also, from the *diurnal*, in having the bones of the skull more fully penetrated by air cells.

B. *Passerine Birds*.—This order is named after the *Sparrow*, which is the type; they are sometimes called the *walking Birds*,

and sometimes the *songsters*; their characters are mostly negative, and are the following:—

Bill of various shape, never waxy at the base, pointed at the tip; legs feathered down to the heel; toes mostly four, but sometimes only three; hallux present always; claws curved and sharp; tail generally with twelve feathers; tarsal bone covered with scales.

The *Passerines* are divided into the following sections, to which some add the Climbing Birds:—

a. *Dentirostres.*

b. *Fissirostres.*

c. *Conirostres.*

d. *Tenuirostres.*

e. *Syndactylæ.*

- (a.) The *Dentirostres* are *Passerines*, whose beak is notched, at both sides, near the point; they are insectivorous, and also eat berries and tender fruit.

They include the *Shrikes*, *Thrushes*, *Nightingales*, *Wrens*, *Wagtails*, and *Titlarks*.

- (b.) The *Fissirostres* have a short, wide, and slightly hooked beak, without any notch, and very deeply cleft, so that the gape of the mouth is very wide, and well adapted for the capture of the insects which they pursue on the wing. These birds are insectivorous and migratory. They include the *Swallows*, *Swifts*, and *Goatsuckers*. These latter are nocturnal in their habits, and have acquired their undeserved name from the fact that they frequent pastures where goats and sheep are herded, in pursuit of the insects attracted by these animals.

- (c.) The *Conirostres* include the passerine birds with a strong conical beak, not provided with a notch. They live chiefly on grain, but are partly insectivorous. This sub-family includes the *Larks*, *Tits*, *Finches*, *Sparrows*, *Crows*, and *Birds of Paradise*. These latter birds, respecting which travellers have told such strange stories, really resemble *Crows* in every respect, excepting plumage.

- (d.) The *Tenuirostres* are passerine birds with a long slender beak, without any notch; it is sometimes straight, and sometimes curved like a bow. They include the *Nuthatches*, *Tree-creepers*, *Humming Birds*, and *Hoopoes*.
- (e.) The *Syndactylæ* are passerines having the outer toe as long as the middle toe, to which it is joined by a membrane. They contain the *Bee-eaters*, *Kingfishers*, and *Hornbills*.

C. *Climbing Birds*. Type—Sulphur-Crested Cockatoo, Fig. 142. *Bill of various shapes, nostrils open; feet adapted for climbing, four toes—two anterior and two posterior; in a few the feet are three-toed, the hallux being absent.* The climbing birds are readily distinguished by having two toes only directed forward, the outer toe and hallux being turned backwards; the sternum has generally two notches behind on each side, and the furcular clavicle is very weak, and their power of flight correspondingly feeble. This remarkable family of birds includes the *Parrots*, *Toucans*, *Woodpeckers*, *Wrynecks*, and *Cuckoos*.

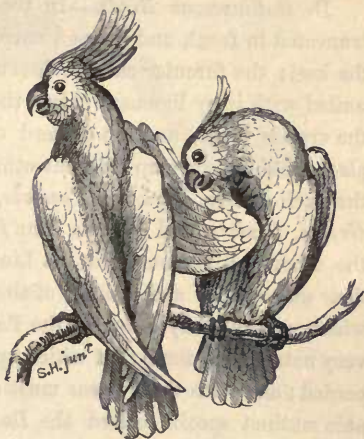


Fig. 142.

The *Parrots* form a most natural genus, containing upwards of 300 species; they are dispersed chiefly in the Southern Hemisphere, the Indian Archipelago, Australia, and South America; Africa possesses only a few species. They have a short neck with twelve vertebrae; the tongue is thick and fleshy, and many of them learn to imitate the human voice. In climbing they hold fast by the bill, and seize their food with one foot in order to carry it to the bill. Many species have bright colours, but they

are gaudy and hard, and afford less satisfaction to the eye than the more harmonious colours of birds that are less splendid: the metallic shades of colour, such as are common in the gallinaceous birds, are not found in Parrots. In Fig. 142 are shown the general form and appearance of these birds; the figure represents the sulphur-crested Cockatoos of North Australia.

The *Toucans* have a large bill, much longer than the head, cellular internally, curved at the tip, with serrate margin; their tongue is horny and feathery; and their tail has ten feathers. They inhabit the tropical regions of America, live in flocks, and feed upon fruits and insects.

D. Gallinaceous Birds.—In these birds the breast bone is truncated in front, and forms a narrow bony band on each side of the keel; the furcular clavicle does not reach the sternum, but is united with it by ligament only; the bones of the arm are short, the crop is large, and the gizzard very powerful; the hallux is placed much higher up than the other toes. This family includes the well-known *Turkeys*, *Peacocks*, *Guinea Fowls*, *Pheasants*, *Grouse*, *Poultry*, and *Pigeons*. The *Pigeons* are distinguished from the other Gallinaceous birds, as Linnæus has well remarked, by their monogamy, and making of their nests in trees, in both of which respects they resemble the Passerine birds. They form a very natural sub-family, of which upwards of 200 species are recorded; and with the *Pigeons* must also be reckoned the remarkable extinct species called the *Dodo*, from the Mauritius, Isle Bourbon, and Rodriguez.

E. Running Birds.—This remarkable family of birds have their wings without quill feathers, and are not adapted for flying; their bill is flattened transversely, and has the tip of the upper mandible projecting beyond the lower mandible. They include the *Ostriches* and the *Apteryx*.

The *Ostriches*, Fig. 143, are birds of large size, inhabiting warm countries, and living upon vegetable food and carrion. As they cannot fly, their breast bone is not provided with the keel

that forms the chief origin of the pectoral muscles in other birds, and their wings are used only as sails to assist in running; the entire structure of the bird is modified, so as to suit its mode of

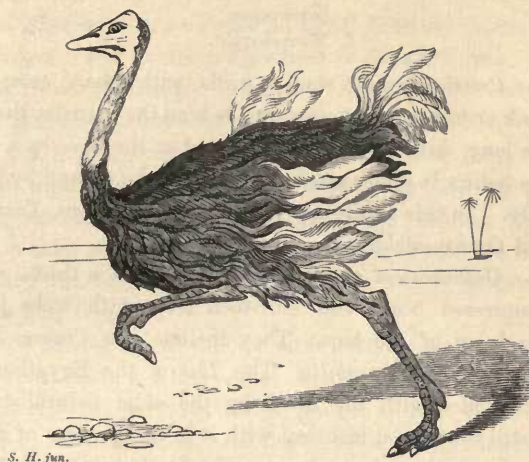


Fig. 143.

life, and the wing bones are found solid, while the thigh bone is abundantly provided with air cells. The *Ostriches* are four in number, viz., the *African Ostrich* with two toes; the *Cassowary*, of the Indian Archipelago; the *Emu*, of New Holland; and the *Rhea*, of South America; they have all three toes, except the Ostrich proper, of Africa.

F. *Wading Birds*.—These birds have their feet stilted for the purpose of wading, and in most of them a large portion of the leg bone (*tibia*) is unfeathered, and covered by a horny substance; they live in fenny districts, on the sea-shore, or on the banks of rivers, and feed mostly on insects, worms, and other small animals; most of the wading birds fly well, and during flight, keep their long legs extended backwards; whereas, in other families of birds, the legs during flight are folded up

under the belly. To the Wading birds belong the following families :—

- a. *Pressirostres*.
- b. *Cultrirostres*.
- c. *Longirostres*.
- d. *Macroductylæ*.

- (a.) The *Pressirostres* are wading birds, with a hard compressed beak or bill, somewhat swollen behind the nostrils; their feet are long, with short toes, connected at the base by a web; the hallux is either absent, or rests on the ground by the tip only. In this family are reckoned the *Plovers*, *Turnstone*, and *Oyster-catchers*.
- (b.) The *Cultrirostres* are wading birds, with a thick, strong, compressed beak, and four-toed feet, with webs joining the bases of the toes. They include the *Cranes*, *Storks*, *Herons*, and *Spoonbills*. The *Ibis* of the Egyptians was confounded with the *Stork* by the older naturalists, and is still considered identical with it in many parts of Europe by the apothecaries, who use the *Stork* as the emblem of their art, confounding it with the *Ibis*, to which bird was attributed the invention of glysters.
- (c.) The *Longirostres* are waders, with a long, slender, and soft bill; nostrils placed in a groove in the bill; wings long, with first quill longest. These birds, like some of the *Pressirostres*, feed on worms and insects, which they search for under the mud by feeling with their slender bill, which is supplied for this purpose with many nerve filaments thrown off by the fifth pair of cerebral nerves; these filaments pass through small bony cavities of the upper mandible. To this family belong the *Sandpipers*, *Curlews*, *Snipes*, and *Woodcocks*.
- (d.) *Macroductylæ*.—Feet four-toed, with toes long, and sometimes lobate; body slender, with narrow sternum. The toes of this family are elongated, for the purpose of enabling them to wade over floating weeds and other marshy vegetation,

and although not web-footed; they can swim with ease when immersed in the water; the body of all these birds is flattened, and their wings short and feeble. They include the *Rails* and *Coots*.

The *Flamingoes* are web-footed birds, formerly grouped with the Waders. The Common Flamingo is found in Asia, Africa, and the South of Europe; it is rose-coloured, with red wings, and black flag feathers, and is three to four feet in height. The legs of the flamingo are very long, and the three front toes are webbed, while the hallux is very short; they feed upon shell-bearing mollusks, insects, and fishes' eggs, securing these by means of their strangely-shaped beak, which is used as a colander for sifting the food grubbed up from the muddy bottom of the marshes they frequent.

G. *Swimming Birds*.—These birds have the lower part of the legs covered with a horny skin; their plumage is thick, and abounds with oily particles, which protect it from the action of the water; the neck is long, and the breast bone large and convex. The swimming birds are divided into four large families:—

- a. *Brevipennes*.
- b. *Lamellirostres*.
- c. *Totipalmates*.
- d. *Longipennes*.

(a). The *Brevipennes* are swimming birds, adapted almost exclusively for a life spent in the water; their wings are so short, that they are of but little use in flying, and are employed almost exclusively as fins in swimming. To this family belong the *Divers*, *Auks*, *Penguins*, and *Puffins*. The *Penguins* live in the seas of the Southern Hemisphere, on the coasts of South Africa, and South America: their upright posture, and gait on land, give them a strange appearance.

(b.) The *Lamellirostres* are swimming birds, characterised by having the margin of their bills denticulate, or furnished

with transverse parallel and crowded plates. The *Duck* Tribe forms a numerous and very natural family, of which upwards of 150 species are known; the *Geese* and the *Swans* are included in this division. In all these birds the dentated edge of the bill is used for straining off the water from the mud that contains the organic substances on which they feed habitually.

- (c.) *Totipalmatæ* are so called because the whole four toes, including the hallux, are united together by a common web; the hallux is placed internally, and directed forwards, and is joined by membrane to the second toe. They include the *Pelicans*, *Cormorants*, and *Gannets*.
- (d.) The *Longipennes* are swimming birds, with bills not serrate in the margin, and with long wings. They include numerous birds met with on the wide ocean in all parts of the globe; the hallux is free, posterior, and simple, and is sometimes altogether wanting. Here belong the *Petrels*, *Albatrosses*, *Sea Gulls*, and *Sea Swallows*. These are all remarkable for their powerful and rapid flight, which they owe entirely to their long and narrow wings, and the powerful muscles by which they are worked.

6. **Reptiles.** These are vertebrate animals, mostly oviparous and cold-blooded, that breathe by lungs. Some of them at first breathe by gills, which disappear when the lungs become developed; and in a few both gills and lungs are present during their whole life.

A. *Skeleton.* The spinal column varies more in reptiles than in any other class of vertebrates; thus in the *Frogs*, there are only eight vertebræ, and in some serpents there are 300 vertebræ. In most of the living reptiles, the body of the vertebra is convex posteriorly and concave anteriorly, forming a true ball and socket joint, and giving great flexibility to the spinal column. In many of the fossil reptiles, this arrangement is reversed, the ver-

tebra being convex anteriorly and concave posteriorly. In the Frogs the vertebræ have long transverse processes; and in the Tortoises, the ribs, in conjunction with the spinous processes of the vertebræ, are changed into broad plates, which form the dorsal shield (*carapace*), that covers these animals above; while the ventral shield (*plastron*) is formed by the expanded sternum, consisting of nine pieces. The plastron of the Hawk's bill Turtle is shown Fig. 144. The inner side of the carapace of the com-

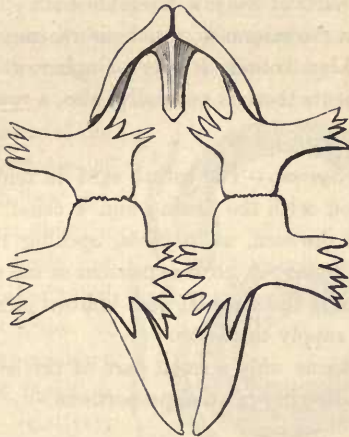


Fig. 144.

mon Tortoise is shown in Fig. 150. When the scapular arch is present, it consists of a scapula and two clavicles, as in birds; but frequently one of the clavicles is suppressed, leaving only the coracoid articulated to the top of the sternum. The typical reptilian pelvis is beautifully shown in the *Alligator* (Fig. 113) and consists of

<i>Ilium</i>,	. . . . .	<i>il.</i>
<i>Ischium</i>,	. . . . .	<i>isch.</i>
<i>Pubes</i>,	. . . . .	<i>p.</i>
<i>Os Marsupiale</i>,	. . . . .	<i>m.</i>

The first three of these bones unite to form the cavity of the

acetabulum (*a*), in which the head of the thigh bone works, and the marsupial bone plays upon the *pubes*, as in the Kangaroo and Opossum. Most of the reptiles are quadrupeds, but the Snakes have no external limbs; traces of rudimentary hind limbs are found in many serpents below the skin, and in a few, rudimentary fore-limbs are to be met with.

Most reptiles have teeth, which are used not so much for dividing or chewing their food, as for holding it fast; and the teeth in the different parts of the jaw resemble each other, and cannot be divided, as in the mammals, into incisors, canines, and molars. In most of the Lizards there is only a single row of teeth in each jaw, but in serpents there is generally, also, a row of teeth in the palate.

B. Nervous System.—The spinal cord in reptiles is always large as compared with the brain; and a canal runs down the entire length of the cord, as in birds, opening into the fourth ventricle of the brain. A great expansion of the cord takes place at the points where the brachial and lumbar plexuses of nerves are given off to supply the limbs.

The brain forms only a small part of the body, as may be seen from the following relative proportions:—

Frog,	$1\frac{1}{2}$
Ringed Snake, . . .	$\frac{1}{10}$
Land Tortoise, . . .	$\frac{1}{1240}$
Turtle,	$\frac{1}{5688}$

The brains of reptiles present, on their upper surface, a great resemblance to those of fishes; the hemispheres possess no convolutions, and are hollowed internally into lateral ventricles.

C. Respiration.—Reptiles are divided into two great sections, according to their mode of respiration:—

1. The *Diplopnæa*, *Double breathers*, or *Naked Reptiles*.
2. The *Haplopnæa*, *Simple breathers*, or *Scaly Reptiles*.

In the *Naked reptiles*, gills are present, either in the young state, as in the Frogs, or during the whole of life, as in the *Proteus*; in the latter case, lungs are also present, and the animals are truly amphibian. The ribs of Lizards and Serpents serve for respiration; and in the Frogs, which have no ribs, inspiration is effected by means of the tongue bone; these animals, keeping the mouth closed, fill its cavity with air through the nostrils, and then closing them, compress the cavity of the mouth by raising the tongue bone, and so inspire air by an act of deglutition. In the tortoises, whose ribs are immoveable, inspiration is effected by a movement of the scapular arch produced by drawing up the clavicle.

The subdivision of the air tubes in the lungs of reptiles is much less perfectly carried out than in mammals and birds, so that the surface of blood exposed to the action of the air in the capillary vessels of the lungs is much smaller relatively than in the other classes mentioned. In many serpents only one lung is present; in the Boa there are two long flat lungs lying along the back behind the stomach and liver, which latter organs are shown in Fig. 145 at *ll*

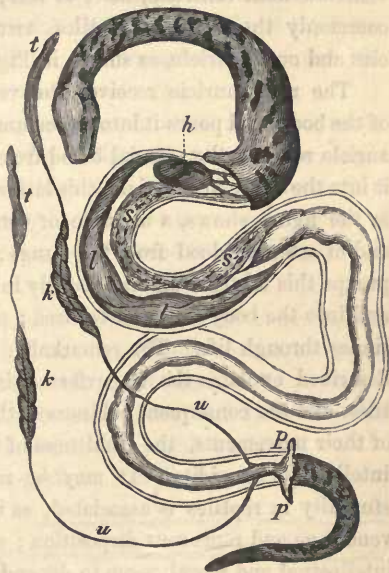


Fig. 145.

and *ss*. In the Tortoises and Turtles, the lungs are broad and flat, and extend along the back as far as the pelvis.

D. *Circulation*.—In Birds and Mammals, the heart consists

of two perfectly distinct hearts, right and left, of which the right receives venous blood from the whole body, and pumps it into the lungs; while the left receives the arterial blood returning from the lungs, and pumps it back again into the whole body. An outline sketch of this arrangement is shown in Fig. 139. In Reptiles, on the other hand, although there are sometimes two auricles and two ventricles, they are never completely separate, but communicate auricle with auricle, and ventricle with ventricle, more or less; more commonly there are in reptiles, two auricles and one ventricle, as shown in Fig. 146.

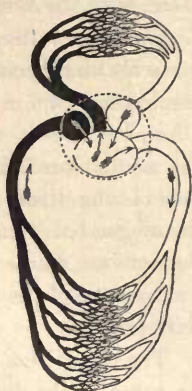


Fig. 146.

The right auricle receives the venous blood from all parts of the body, and pours it into the common ventricle; while the left auricle receives the arterial blood from the lungs, and also pours it into the common ventricle; this latter organ, therefore, contains, as the figure shows, a mixture of venous blood from the body, and of arterial blood from the lungs; and when it contracts, it pumps this mixture simultaneously into the lungs to be oxidated, and into the body to be carbonised; and so the circulation continues through life. The remarkable structure of the heart just described explains the imperfect oxidation of the blood in reptiles, and the consequent coldness of their blood, the sluggishness of their movements, the feebleness of their sensations, and their intellectual stupidity. It may be remarked, in passing, that stupidity in reptiles is associated, as it often is in man, with a venomous and rancorous disposition; and that these defects, both intellectual and moral, seem to depend on an imperfect oxidation of the blood corpuscles.

E. Digestion.—The salivary glands are sometimes wanting, and sometimes only slightly developed in reptiles. The stomach of

serpents, as shown in Fig. 145, *s, s*, is scarcely distinguishable from the œsophagus and intestine; it presents no curvature, but its walls are thicker than those of the œsophagus, and contain many longitudinal folds. In the Crocodiles, the stomach is very muscular, and exhibits an analogy to the gizzard of birds; this resemblance is shown especially in the tendency of these animals to swallow, like birds, small flint stones, which remain in the muscular stomach for years, and serve the purpose of triturating the food, which is swallowed whole, as the mouth has no teeth suitable for mastication.*

The length of the digestive canal in most reptiles is only about twice the length of the body, estimated in a straight line from the mouth to the vent, and omitting the tail; if the latter organ be included in the length, the digestive canal equals the length of the whole body in the Lizard tribe.

The separation of the large and small intestines is frequently marked by a cæcal valve, and sometimes by a cæcal tube, especially in the highly organised Lizards. The gut terminates in a cloaca, as in birds, which may be regarded as an enlargement of the rectum, and receives the excretions of the intestines, kidneys, and genital organs.

F. *The Liver, Pancreas, and Kidneys.*—The *liver*, in the *Dog-headed Boa*, Fig. 145 *l, l*, is a large organ commencing just below the heart (*h*); it lies beside the stomach, *s, s*, and occupies a considerable portion of the entire length of the body; and it contains, in most reptiles, as in birds, a gall bladder.

The *pancreas* is always present, and is often a large organ, varying much in form.

* I have dissected an *Alligator*, in which death was occasioned by peritonitis, caused by the perforation of the stomach by lumbrical worms; and yet the stomach contained many flint stones, which must have endangered the existence of the worms.

The *spleen* is usually present, but is generally small.

The *kidneys*, Fig. 145, *k, k*, are much elongated in the serpents; they are thick and oval in the Tortoises; and are longitudinally oval in the Lizards and Frogs. They are usually notched in the margin, or divided into lobes by transverse grooves, which in Serpents resemble the convolutions of the brain.

7. Classification of Reptiles.—The Reptiles are divisible into two sections: the *Amphibians* and the *True Reptiles*, according as they breathe by gills and lungs, or by lungs only.

A. *The Amphibians, or Diplopnæa*, are *Naked Reptiles*, that breathe by gills as well as lungs, and possess the following characters:—

Gills deciduous or persistent; skin glutinous, smooth, almost always quite destitute of scales; occipital condyles double—one at each side of the foramen. The Naked Reptiles may be divided into three very natural orders, corresponding with the Serpents, Lizards, and Chelonians among the *Scaly Reptiles*.

- a. Serpentlike Amphibians.—*Ophidobatrachia*.
- b. Lizardlike Amphibians.—*Saurobatrachia*.
- c. Tortoiselike Amphibians.—*Chelonobatrachia*.

(a.) *Serpentlike Amphibians* (*Ophidobatrachia*).—*These reptiles have no feet, their body is snake-like, and their skin is wrinkled like that of a worm, by transverse rings.* This very remarkable group of Amphibians contains only one family, the *Cæcilians*, found in Java, Ceylon, Guinea, and South America. They are furnished with a pair of small gills, in early life, which disappear as the animal grows older, when it breathes altogether by means of lungs, like those of a serpent. It differs from the snake, in having very small or no eyes, and in having the vent placed almost at the extremity of the tail; this greater length of the gut, as compared with serpents, is to be explained by the fact, that the *Cæcilians* feed largely upon vegetable as well as animal

food. They were formerly confounded, by the best naturalists, with serpents; but the discovery, by Müller, in 1830, of two gill-openings in a young specimen in the Museum at Leyden, has placed their Amphibian character beyond doubt.

- (b.) *Lizardlike Amphibians* (Saurobatrachia).—The lizardlike Amphibians form a most natural group; they have either four feet, or two anterior only, and always retain their tail through life. Many of these amphibians, like *Siren* and *Proteus*, have three pairs of external gills, which are used through life as the chief organs of respiration; others lose their gills as they advance in age, but retain a gill-opening behind the head through life; others, again, as the *Salamanders*, breathe altogether by lungs in the adult state. The best known of these remarkable Amphibians are the *Tritons* that frequent stagnant pools of water in this country (Fig. 147). These little animals are most voracious, and devour aquatic insects, larvæ of various flies, and even tad-

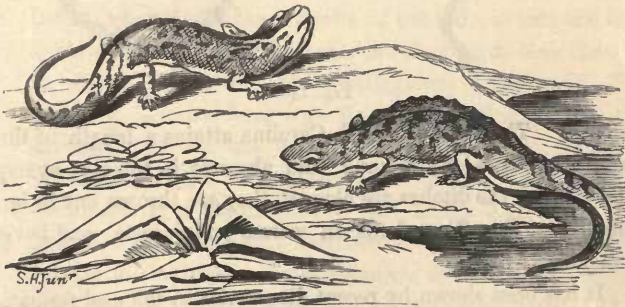


Fig. 147.

poles in large numbers; they swim by means of the tail chiefly, and throw back the legs to diminish resistance. The young of this Salamander have their fore legs developed previous the hind legs, and are furnished with three pairs of external gills, which they retain until they are three months

old, when they are cast off together with all traces of gill apertures, and the animal thenceforward breathes by lungs only; it has been remarked that *Tritons* hatched late in the season do not cast their gills until winter has passed, so that they are protected from cold by the water, and they continue to grow almost as fast as the *Tritons* that have cast their gills at the usual period.

The *Mud-eel* (*Siren*) of Carolina is a very remarkable form of lacertine Amphibian; its skeleton is represented in Fig. 148. Its gills continue through life, and its hind feet are never de-

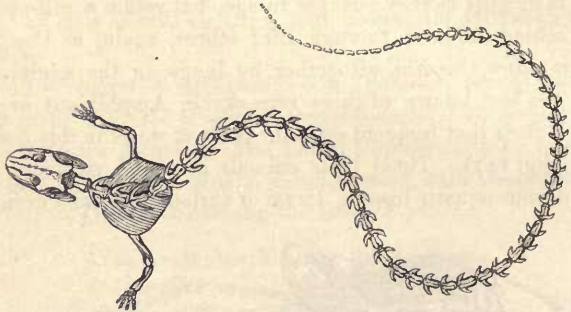


Fig. 148.

veloped. The *Siren* of South Carolina attains a length of three feet; it lives chiefly in mud, and abounds in the rice swamps, where, when the ditches are cleared, they are thrown out in large numbers. The *Siren* feeds on worms and insects, and is very voracious.

It has been shown by recent discoveries in the coal formation of Kilkenny, that lizard-like Amphibians abounded in the swamps in which those coal fields were formed, so that the animal life of the remote period of the coal epoch corresponded more closely than has been hitherto supposed with that of swampy districts in subtropical countries in our own time.

The largest of the amphibian lizards are the Salamander of

Japan (*Cryptobranchus Japonicus*), which attains a length of three feet, and a corresponding amphibian from the North American rivers, which attains a length of two feet, and is called *Tweeg* by the Delaware Indians, while our American cousins call it *Hell-bender* and *Mud-devil*.

(c.) The *Tortoiselike Amphibians*, Batrachia, or Chelonobatrachia, are the best known of all the amphibians, as frogs, toads, &c. The skeleton of this group of amphibious reptiles, like that of the tortoises among the true reptiles, is almost rigid, leaving only the limbs free, and it occasionally presents traces of a dorsal shield, as in the true tortoises. These amphibians are all oviparous; and the larvæ breathe by internal gills; at first, external gills are present also, as in the larvæ of *Salamanders*, and have the appearance of finger-shaped tubes, divided into two, three, or more lobes. The external gills disappear a few days after birth, and the internal gills of the tadpole alone remain; these are attached to four cartilaginous gill-plates connected with the tongue bone; when the metamorphosis of the tadpole into the frog is completed, the gills disappear, and the tongue bone changes its shape, having lost the cartilaginous gill-plates. The tadpoles, acquire hind legs first, thus differing from the larvae of the lacertine amphibians; and the tail, which is often very large, is removed by a process of resorption, commencing at the extremity, and finally disappears altogether. The Frogs and Toads are easily distinguished from all other amphibians by the absence of tails, their peculiar squat figure, large mouths, and gigantic hind limbs. They are so well known as to require no further description in an elementary work.

B. The *True Reptiles*, or *Haplopnæa*, possess the following characters:—

Furnished with scales; breathe during their whole life by means of lungs only; the occipital condyle is single, and placed below the foramen.

They are divided into three well-known and most natural groups, which form the types to which the groups of the amphibians have been referred—

- a. Serpents, *Ophidians.*
- b. Lizards, *Saurians.*
- c. Tortoises, *Chelonians.*

(a.) *Serpents* or *Ophidians*.—The most obvious character of these reptiles is the absence of limbs; but this characteristic is not sufficient, for it would include the *Cæcilians*, already described as *Ophidobatrachians*, which are not true reptiles, but amphibians, as they breathe by gills in early life. The eyes of serpents are covered with an immoveable pellucid eyelid; their tongue is bifid, exsertile, and is used as an organ of touch. Serpents are reptiles in the strictest sense, for the absence of limbs of any kind reduces their locomotion to that of worms, and they progress by alternate bendings of their ribs to and fro, as myriapods and caterpillars do, by the alternate bendings of their numerous feet.

A large proportion of serpents are innocuous; but among those that are venomous are to be reckoned animals more dreaded by man than any others. It is estimated that one-eighth part of the known snakes are more or less venomous. In most of these there is a single *poison fang*, attached by a sort of hinge-joint to the upper maxillary bone; this fang lies in the gum pointed backward, when not in use, but is lifted from the gum and pointed downward when its owner is prepared to bite; two or three other poison fangs are kept in reserve, placed above and behind the fang in use, and ready to grow into its place if it be displaced or destroyed. Through the poison fang there passes a canal which opens close to the point of the tooth, by a fine fissure, on its front surface. The poison gland which distils its secretion into the perforated fang is placed under and behind the eye upon the upper jaw, and is involuntarily compressed by

the action of the temporal muscle in closing the mouth. The poison itself is a greasy gelatinous fluid, without taste, and drying in the air into scales, and retains its poisonous qualities for a long time (like *vaccine*), if not exposed to heat. The poison of snakes is said to be innocuous if swallowed, but if introduced into the blood, it at once produces its deadly effects, which resemble in many respects the effects of *typhus* and other animal poisons; thus in *typhus* fever, the only chance of saving life when the first sound of the heart has ceased, consists in the administration of alcohol, which then produces no intoxicating effect upon the brain; and it is commonly believed in America, that if a person bitten by a rattlesnake can be made drunk, he will recover, whereas it is a mortal sign to find his system insensible to the action of alcohol.

Amongst the most deadly of the venomous serpents may be mentioned the *Rattlesnake* of North America, the *Naja*, or *Spectacled Snake* of India, and the *Puff-adder* of South Africa.

The *Water Snakes* are all venomous, and live in droves at the mouths of rivers, and occasionally far out at sea, attaining a length of four or five feet, and swimming with the head erect and lifted from the water, ready to strike with their dangerous fangs; in these animals the tail is flattened so as to serve as a propelling skull. Cælian was acquainted with the fact that Water Snakes swam in droves in the Persian Gulf and Indian Ocean. They are unknown in the Mediterranean, and the *Hydrus*, or Water Snake mentioned by Aristotle, and so well described in the *Battle of the Frogs and Mice* of Homer, was probably a variety of the harmless *Ringed Snake* (*Coluber natrix*) of Europe, which occasionally takes to the water in search of its food.

ὕδρος δ' ἐξαπίνης ἀνεφαίνετο—δεινὸν ὄραμα
ἀμφοτέροις—ὀρθὸν δ' ὑπὲρ ὕδατος εἶχε τράχηλον.

The *Pythons* and *Boas* include the largest of the snakes, and kill their prey, not by venomous fangs, but by encircling them

in the folds of their powerful bodies; some of them measure upwards of twenty feet in length, and they are all characterized by spurs or rudiments of hind feet, like moveable hooks, placed one at each side of the vent.

(b.) *Lizards or Saurians*.—These reptiles are characterized mostly by the possession of four legs, but a few of them have two only, and more rarely none at all; they resemble serpents on legs, and those which have no legs, or only rudimentary ones, were formerly united with the serpents; the eyelids, however, of these snake-like saurians are different from those of the true snakes, for they are always moveable and not fixed.

Among the saurian reptiles are reckoned *Slowworms*, *Geckoes*, *Iguanas*, *Chameleons*, *Lizards*, and *Crocodiles*.

The *Slowworms* have no feet visible, and resemble snakes in almost all their external characters; they possess, however, as may be found on dissection, the rudiments of a scapular and pelvic arch. They are distinguished from snakes by their moveable eyelids, opening by a longitudinal slit, and by the absence of the forked tongue characteristic of serpents. The English Slowworm has a copper-coloured or brownish back with a silvery glance, and a longitudinal black stripe on the middle, and the belly is blueish. When frightened, this little animal stiffens its muscles so rigidly, that its tail can be easily broken off, as if it were brittle; from this curious fact it derives its name *Anguis fragilis*. The *Slowworm* is viviparous, feeds on slugs, insects, and earth worms, and hides in winter underground, becoming torpid.

The *Geckoes* form a remarkable group of Saurian Lizards, nocturnal in their habits; their eyes, like those of serpents, are covered by a transparent fixed eyelid, behind which the eye moves freely; they are provided with a leaf-like expansion at each side of the toes, by means of which they climb vertical walls, or even walk along a ceiling, like flies; in this case the

membranous expansions of the toes must act as suckers, so that the weight of the body is sustained by atmospheric pressure; their toes, also, are sometimes provided with retractile claws, like those of a cat. These animals feed on insects at night, and utter a sound resembling *Gecko*, from which circumstance they have been named—they attain a length of six to ten inches.

The *Iguanas* are remarkable for the crenated or serrated edges of their thick fleshy tongues, and the crest that commonly runs down the back and tail. A single species is common to the South of Europe, the North of Africa and Asia Minor; many others are found in Asia, and in South America they abound. They are also represented by many remarkable and closely allied fossil forms. Some of them, called *ground-iguanas* have a flattened head and depressed body, while the others, called *tree-iguanas*, have the body compressed latterly. Some of the *Iguanas* change colour, like the chameleon, and most of them are regarded as excellent food. They are among the most intelligent of the reptiles, and are capable of being made “pets.”

The *Chameleons* are readily distinguished from all the other Saurians, by their remarkable tongue; this organ is long, exsertile to a considerable distance, and is fleshy, round, and glutinous. The Chameleon can dart this protractile tongue at a fly with the swiftness and certainty of an arrow, so that the spectator sees the fly suddenly disappear, without being able to notice the opening of the Chameleon's mouth, or the extrusion of his tongue. Its tail is prehensile, but it is never known to lay hold of its prey, either with tail, or feet, or mouth. The Chameleon possesses two horizontal eyelids, which unite to form a single circular eyelid, with a small aperture in its centre, in front of the large eye. The following accurate description of this curious animal is given by Aristotle.* “The Chameleon's eyes are placed in a hollow, and are very large and round, surrounded with skin like the rest of

* History of Animals, Bk. ii. 7.

its body, and in the middle is left a small aperture through which it sees; this is never covered with skin; the eye is turned round in a circle, and it can direct its vision to any side, so that it can see where it will. The change in the colour of the skin takes place when it is filled with air; it can acquire either a black colour, like that of the crocodile, or ochreous, like that of the lizard, or spotted with black, like the panther; and this change takes place over the whole body, for the eyes also change like the rest of the body, and so does the tail."

The *Crocodiles* (Fig. 149) are often separated as a distinct order from the Lizards. They live in fresh water, are very

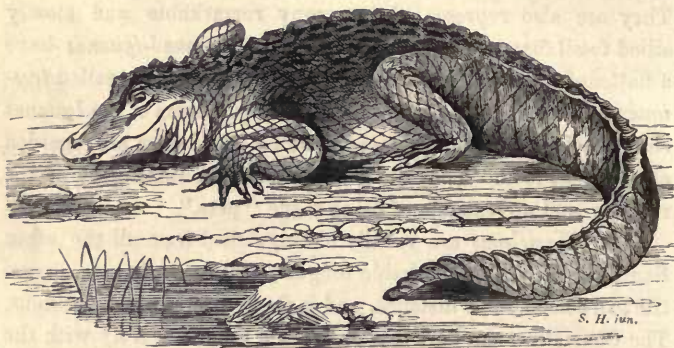


FIG. 149.

voracious, and are therefore called *muggers* by the Hindoos; by day they frequent the land, robbing hen roosts, and attacking dogs and children, and at night they remain in the water, and look for fish and carrion.

The Crocodiles are found both in the Old World and in the New; those of the Old World being distinguished from those of the New World by trifling characters depending on the width of the upper jaw and the manner in which the fourth tooth of the lower jaw locks into the upper.

The best known species are the Crocodile of Africa (*Croco-*

dilus vulgaris), described by Herodotus and Aristotle; the Gavial of India (*Crocodylus Gangeticus*), and the Alligator, or Cayman (*Crocodylus Mississippiensis*).

Aristotle observes that "all animals move the lower jaw except the river crocodile, which moves the upper jaw only." He also observes that the crocodile resembles the fishes in having a tongue, not free, but flat and adherent to the lips, all round the mouth. He also states that "the river crocodile produces as many as sixty eggs, which are white, and sits upon them for sixty days, for they live a long while. A very large animal is produced from these small eggs—for the egg is not larger than that of a goose, and the young is in proportion—but, when full grown, the creature measures seventeen cubits. Some persons say that it grows as long as it lives."

Modern travellers have ascertained that the Nile Crocodile attains a length of eighteen feet, but it is now seldom met with in Lower Egypt, in consequence of the increasing population and consequent traffic on the river.

The Crocodile of the Mississippi is called Alligator by the English, a word corrupted from the lagarto (*lacerta*) of the Portuguese; and the great Linnæus called the crocodile *Lacerta crocodilus*; other travellers call the American crocodile the Cayman (*Kaaiman*). He is often found fourteen feet in length.

The Crocodile of the Ganges (*Gavial*) attains a length of more than ten feet, and is very voracious and destructive; for, although it feeds principally on fish, it often comes ashore, and plunders the poultry yards that lie near the river.

The priests of Egypt were well aware that the crocodile, like most carnivorous animals, could be tamed through delicate attentions paid to his stomach; and, by bestowing extraordinary care on his food, succeeded, as Herodotus relates, in inducing the crocodiles to live in the temples without displaying any portion of their natural ferocity of disposition.

(c.) *Tortoises or Chelonians*.—These remarkable reptiles are immediately recognised, by having their bodies covered with a double bony shield, the upper composed of confluent ribs, and the lower of the sternum. The scapular and pelvic arches, supporting the fore and hind limbs are placed altogether under the covering of the bony shields, as shown in Fig. 150, which represents the skeleton of the common Land Tortoise, with the ventral shield (*plastron*) removed. Two of

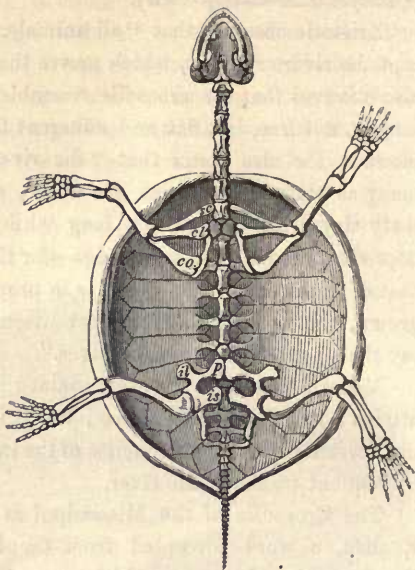


Fig. 150.

the bones forming the scapular arch, viz., the Clavicle and Coracoid, *cl* and *co*, are placed, as in birds, so as to form a double clavicle, *furculur* and *coracoidal*; but in the tortoise, the extremities of the furcular clavicle are not united to each other, but attached by broad ligaments to the sternum, which has been removed in the figure.

The Scapula, *sc*, forming the third bone of the arch, differs from the scapula of all other animals; it is a long cylindrical bone, placed inside the ribs, and articulated by strong ligaments to the first rib, at its point of junction with the spine. The whole of the muscles that move the arm are necessarily placed under the ribs, and the same arrangement prevails in the hind

limbs. In the pelvic arch, the two bones, *pubes* and *ischium*, *p* and *is*, correspond with the clavicle and coracoid in position and use, and the third bone, *ilium*, *il*, corresponds with the scapula; and all are placed, together with the muscles arising from them that move the thigh, under the dorsal shield (*carapace*). In the vertebral column, the only moveable bones are the seven cervical and first dorsal vertebræ, two or three of the sacral, and the caudal vertebræ.

The sternal shield (*plastron*) consists always of nine pieces, as shown in Fig. 144, which represents the plastron of a Hawk's-bill Turtle. In the turtles, or sea tortoises, there are open spaces between the bony pieces, which are occupied by fibro-cartilage; in the land tortoises, however, the nine pieces of the sternum are united together by sutures, without any cartilage interposed. The tortoises are long-lived, very tenacious of life, and show a long continuance of irritability in parts that have been removed from the body. Most of them live on vegetable food, and on mollusks also.

The tortoises are divided by Aristotle into the land tortoises (*χελώνη χερσαία*), the sea tortoises (*χελώνη θαλαττία*), and fresh water tortoises (*ἐμύς*). Modern naturalists follow this division, and describe—

- a. Land Tortoises, *Chersians*.
- b. Turtles, or Sea Tortoises, *Thalassians*.
- c. Pond Tortoises, *Elodians*.
- d. River Tortoises, *Potamians*.

(a.) *Land Tortoises*—Have the body short, oval, convex, covered with a carapace and plastron; feet four; teeth none. The feet are stumpy, nearly of equal length, with toes little distinct, united, and covered by a thick skin, which gives the foot almost the appearance of a hoof.

(b.) *Sea Tortoises*—Have the carapace greatly depressed, and the pairs of feet, unequal in length, flattened out into the

form of oars, or solid fins, like the flippers of a seal, and formed of the toe bones united in a horny case of skin.

- (c.) *Pond Tortoises*—Have the toes separately moveable, furnished with crooked claws, and frequently united by a web at the base, like the feet of swimming birds.
- (d.) *River Tortoises*—Have the feet palmated, like the last, but are furnished with three claws only on each foot; their pointed and cutting beak is furnished externally with lips, which are not met with in the other tortoises; and their bony carapace is covered with a leathery skin.

8. **Fishes.**—The *Fishes* form the fourth and last of the subdivisions of the Vertebrate Animals; they are cold-blooded, live always in water, and breathe by gills. The body of a fish may be divided into head, trunk, and tail; and there is no neck, for the gills are placed immediately behind the head, and thus the cavity of the chest is quite close to that of the mouth. In Fig. 151 is represented the *Cod fish*, which will serve to give a

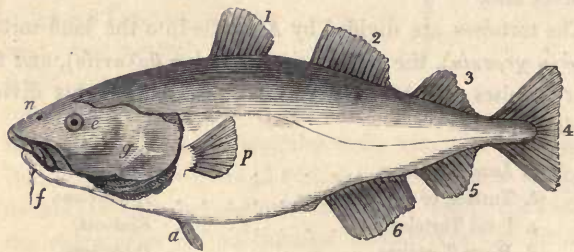


Fig. 151.

general idea of the different parts and organs of which a fish is externally composed.

The apertures of the nose and eye are shown at *n* and *e*, and a filiform tentacle or feeler, present in many fishes, is shown appended to the lower lip, at *f*.

The *gill covers* are shown behind the head, at *g*, and are formed of bony plates, open at the back, so as to allow the water, which

is admitted to the gills through the mouth, to pass away backwards, after it has performed its duty of aerating the blood that circulates in the capillary vessels of the gills.

The *fins* are of two kinds; either placed symmetrically on the middle line of the back, belly, and tail, as—

<i>Dorsal fins,</i>	. . . . .	1 . 2 . 3
<i>Caudal fins,</i>	. . . . .	4
<i>Anal fins,</i>	. . . . .	5 . 6;

or arranged in *pairs*, at each side of the body, as shown at *p* and *a*, called

<i>Pectoral fins,</i>	. . . . .	<i>p.</i>
<i>Abdominal fins,</i>	. . . . .	<i>a.</i>

These latter, or paired fins, correspond to the fore and hind limbs of quadrupeds, and are to be regarded as strictly homologous with those organs.

A. Skeleton.—The skeleton of fishes is not always composed of true bone, for in many fishes, such as *Sharks*, *Sturgeons*, and *Rays*, the substance of the skeleton consists of cartilage instead of bone; and it is remarkable that most of the fishes of the older periods of geological history were cartilaginous and not bony. The number of vertebræ is very different in different fishes, and ranges from 17 to upwards of 100 distinct bones. Of these vertebræ, the tail is generally composed of more than half; for as it is the organ of locomotion, the other parts of the body are made subservient to its use, and the viscera are all pushed forward, in order to make room for the great masses of lateral muscles that move it.

The *pectoral* fins of fishes (Fig. 151, *p*) correspond to our arms, or to the wings of birds; they are attached to an osseous belt, formed by two scapular arches, that descend, in the bony fishes from the skull, and in the cartilaginous fishes from the spinal column.

The *abdominal* fins, or hind legs (Fig. 151, *a*), are attached to

a triangular bone with its point directed forwards, which meets that of the opposite side in the middle line of the abdomen, and is generally united to it by suture; these bones constitute the pelvic arches.

B. Nervous System.—The total mass of the spinal cord, in relation to the brain in fishes, is very large; the cord is divided on its upper and under surfaces by a longitudinal fissure; and in its interior, as in reptiles, there runs a narrow canal that expands anteriorly into the fourth ventricle of the brain. The brain is very small, in relation to the body, as well as to the spinal cord, and rarely reaches one-thousandth part of the body weight. The brain exceeds in width the spinal cord very slightly; and instead of forming one mass, more or less continuous, as in higher animals, is flat and elongate, consisting of eight lobes, lying beside each other, and connected by nerve tissue.

C. Respiration.—The respiration of fishes is effected by means of *gills*, which, as is well known, consist of fibrous leaflets arranged in double or single rows, on bony or cartilaginous arches, connected with the tongue bone. In bony fishes and Sturgeons, these branchial arches are free on the outer side; the water is taken in by the mouth, and afterwards expelled by the gill apertures placed behind the gill covers (*g*, Fig. 151). In the Sharks and Rays, the leaflets of the gills, mounted on the gill arches, are enclosed in separate cavities, divided from each other by membranous sheets, that run from the arch of the gill (between the two leaflets attached to it), outwards to the skin; these separate gill cavities open externally by five transverse slits; and respiration is performed exactly as in the other fishes, by means of the particles of air enclosed in the current of water passing continually from the mouth, over and between the gill leaflets, to the gill apertures, through which the water finally escapes.

D. Circulation.—The heart, in fishes, is reduced to a condition still more simple than is found in reptiles; no arterial blood

whatever circulates in the heart of the fish; the whole of the venous blood returning from the body is received (Fig 152) into a single auricle, and passed into a single ventricle, from which it is pumped direct into the pulmonary artery leading to the gills; the arterialized blood returns from the gills, not into the heart, but into the general circulation of the body; thus, in fishes, the blood performs only one circuit, while in mammals and birds it performs two circuits—one through the body, and one through the lungs. Valves are placed between the auricle and ventricle, which prevent the return of blood into the auricle when the ventricle contracts; and other valves are placed at the junction of the pulmonary artery with the ventricle, which serve a similar purpose. The ventricle of the heart is frequently tetrahedral in form, receiving the blood from the auricle on one of its faces, and discharging it into the artery through the vertex of the pyramid; between the ventricle and the pulmonary artery is often seen an enlargement of the latter, pear-shaped, which is called the bulb of the artery, and possesses considerable contractile power, acting as a sort of supplementary ventricle, to propel the blood into the capillaries of the gills. In sharks and other fishes, the resemblance of the arterial bulb to a second ventricle is made still more striking, by the existence of valves, not only between the ventricle and the bulb, but also between the bulb and the pulmonary artery.



Fig. 152.

The heart is placed behind and between the gills, just above the junction of the two clavicles of the pectoral fins. It is remarkable that the muscle of the heart is always red, as in the higher animals, although the muscles of the body are pale or even white. The action of the heart is sluggish, being from twenty to thirty beats in the minute, and its irritability continues in

many fishes, for hours after death, and even removal from the body.

E. *Digestion*.—The œsophagus in most fishes is almost undistinguishable from the stomach, into which it opens by a large aperture; the stomach varies much in shape in fishes feeding on different kinds of nourishment, but it generally opens into the small intestine, by a narrow pylorus provided with a membranous fold or valve. The difference between the entrance and exit of the stomach, is well seen in the *Rock cod*, which feeds upon crabs; in this animal, the opening from the gullet into the stomach is sufficiently large to allow a moderately sized crab to be swallowed with ease, while the passage of the pylorus is not much larger than the head of a good-sized pin. The process of digestion of a crab by the *Rock cod* is therefore performed like that of a mouse by an Owl; the gastric juices macerate and dissolve the soft parts of the food, while the bones and skin, or shell, are rejected after digestion, by an act of vomiting.

The *pancreas* is present in some fishes, but not in all; some cartilaginous fishes—*Sharks* and *Rays*—present this organ in its usual form; in the *Pike* and *Eel* it is readily found, and occupies its proper place in relation to the gall duct; in many other fishes, a pancreas properly so called is absent, but its function is fulfilled by a number of cæca, or *pyloric appendages*, as they are called; these are attached to the intestinal canal in the neighbourhood of the pylorus, and secrete and discharge into the small intestine a tenacious slimy fluid, which probably performs the function of the pancreatic juice. In some fishes, as the *Sturgeon*, we find present both pyloric appendages and a true pancreas; while in others, as the remarkable *Mud fish*, both are entirely absent.

F. *Liver and Kidneys*.—Fishes possess a large soft *liver*, saturated with oil, which is now used in commerce and medicine for many purposes. It fills almost the whole of the abdominal cavity, and interpolates itself between the folds of intestine, as

is usual among the Mollusks. It is generally furnished with a gall bladder, which communicates with the intestine close to the pylorus.

Kidneys are found in fishes, placed behind the peritonæum, with the swim bladder, close to the spinal column; they generally extend from behind the head to the vent; they are of a loose spongy texture, like those of birds and reptiles; and are often united together at their posterior extremities. These kidneys open out into a common expansion, or urinary bladder, which lies upon the rectum, and opens behind the anus. This latter peculiarity distinguishes Fishes from all other Vertebrates.

9. Classification of Fishes.—The classification of fishes has puzzled the most skilful Naturalists, and we cannot be yet said to possess any principle of classification that is truly natural. I shall adopt that sketched out by Müller, as the best yet proposed. Müller gives the following subdivisions of the whole class:—

- A. *Leptocardians*.
- B. *Cyclostomes*.
- C. *Sirenoids*.
- D. *Placoids*.
- E. *Ganoids*.
- F. *Teleosteans*.

A. *Leptocardians*. Heart absent, replaced by pulsating artery; brain absent, replaced by obtuse termination of spinal cord; gill-sack in front of gullet, and included in body cavity; blood pale. These curious fishes are the lowest form of vertebrate animal; they are represented by a single species only, the *Lancelet* (*Amphioxus lanceolatus*), about two inches in length, which buries itself in the sand of the shore, and was long regarded by naturalists as a kind of slug. The extremely low organization of this fish is shown by the absence of brain, and of heart; also by the fact, that the gills are placed in the body cavity that contains the eggs and seed, which are discharged,

through the same aperture (*porus abdominalis*) in front of the vent, through which the water escapes after it has oxidated the gills.

B. *Cyclostomes*.—*Heart distinct, without arterial bulb; blood red; gills six or seven at each side, and furnished with external openings through which the animal can breathe independently of the mouth.* The mouth of these fishes is destitute of a lower jaw, the place of which is taken by a modification of the tongue bone; and they can attach themselves, by suction, to stones or other substances by means of the ring of lip that surrounds the opening of the mouth; under such circumstances, they inspire and expire water, by means of the external gill openings.

The best known of the Cyclostome fishes are the *Lampreys* and the *Hag fishes*.

In the Lampreys, (Fig. 153), there are seven gill apertures at

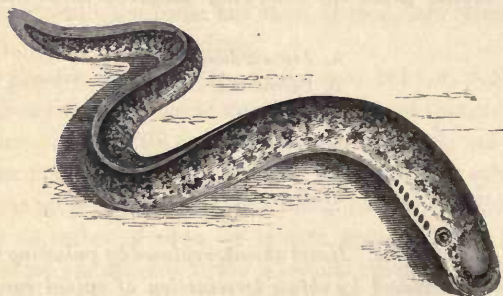


Fig. 153.

each side of the body, which open internally into a common respiratory tube, that in its turn opens into the gullet by an aperture closed by a valve. When the mouth is free, the water enters through it into the respiratory tube, as in other fishes, and flows out through the gill apertures; but when the mouth is attached to a stone or fish, or other body, the water of inspiration is drawn in through the gill openings, and again expelled from them, by

alternate currents, produced by the muscles of the mouth and gullet.

C. *Sirenoids*.—These remarkable fishes are considered to be a connecting link between the fishes and reptiles; the skeleton is partly cartilaginous, including the bodies of the vertebræ; fore and hind feet, or pectoral and ventral fins, resembling awl-shaped filaments (Fig. 154); body covered with circular scales invested

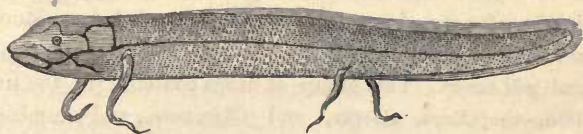


Fig. 154.

with skin. These animals are known to us by means of the *Mudfish* (*Lepidosiren*) of Brazil, the Gambia, and the rivers of the East Coast of Africa. They breathe partly by gills furnished with vertical apertures placed in front of the fore limbs, and partly by swallowing air, which they rise to the surface of the water to procure, and which is supposed to oxidate the blood, by gaining access to the swim bladder, from the gullet; when young, they are also furnished, like some of the amphibians, with accessory external gills, which afterwards disappear. The auricle of the heart is partially divided into two chambers by a muscular network, one of which chambers receives venous blood from the body, and the other receives arterial blood from the swim bladder; thus the circulation is reptilian; on the other hand the urinary bladder opens behind the rectum, an arrangement essentially fish-like. The *Mudfish* inhabits districts flooded periodically by tropical rains, and leads the active life of a fish, as long as the waters prevail; but when the flood is passing off, this curious animal burrows into the mud, which is soon baked into a hard crust by the sun; an aperture is, however, left by which air gains access to the fish, and reaches the swim bladder. Mudfishes, dug out in balls

of clay, and wrapped in a thick coat of mucus, have been brought frequently to this country, and have been restored to animation by moistening the hard clay with water. Several of them, thus restored to life, have been kept for months in the Zoological Gardens of Dublin, where their singular habits attracted much attention among naturalists.

D. *Placoids*.—*Skeleton entirely cartilaginous (excepting the teeth, and defensive spines of the back); tail recurved upwards, with caudal fin inferior; skin generally rough with small bony points or scales; mouth under the head; no swim bladder; gills fixed, without gill covers.* This group of fishes contains, in the living creation, the *Rays*, *Sharks*, and *Chimæras*, and numberless multitudes of fishes in geological epochs long passed away. The *Angel fish*, Fig. 155, which is a *Shark*, but resembles the *Rays* in appearance, may be selected as a specimen of this extensive group of fishes. In this fish, the mouth is placed nearer the snout than in the other sharks; it is furnished with two temporal apertures shown behind the eyes, which communicate with the mouth, and are used for the admission of water to the gills, which open as usual in five vertical slits placed on the sides of the neck, at its narrowest part. The large apertures used for admitting water to the mouth and gills are called spout holes. This fish occurs in large numbers on

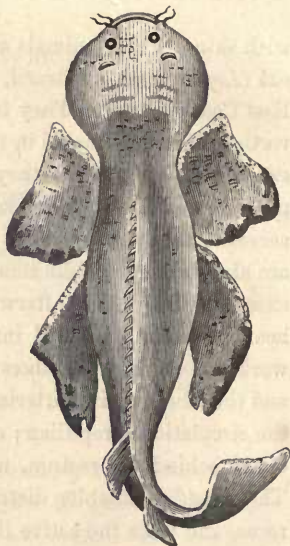


Fig. 155.

our coasts, and does much mischief by devouring soles and other flat fish, of which it seems to be particularly fond. Sharks have been caught at the Bermudas, twenty feet long, and at Rangoon

they have been found to measure as much as thirty-five feet in length.

E. *Ganoids*.—*Skeleton either cartilaginous or bony ; gills free, covered by a gill cover ; scales bony, covered with a glassy enamel ; swim bladder opening by a duct into the gullet (as in Sirenoids) ; tail generally heterocercal.* The fishes named *Ganoids* by Agassiz, like the *Placoids*, abounded in former ages of the world, almost to the exclusion of all other kinds of fish ; at present they are represented by three families, the *Sturgeons*, the *Lepidostids* of North American rivers, and the *Polypters* of African rivers. Müller regards the essential characters of the *Ganoids* to be as follows :—They are provided, like the *Placoids*, with several rows of valves in the pulmonary artery ; they have free operculated gills, and abdominal fins placed very far back.

The royal Sturgeon is shown in Fig. 156, and may be taken



Fig. 156.

as a type of the *Ganoids* ; it possesses an elongate body, protected and made pentagonal in cross section by five rows of bony shields ; it has a protractile toothless mouth placed under the muzzle, and a blow hole, with a single gill opening protected by a gill cover at each side of the head ; and a heterocercal tail.

The *Lepidostids* and *Polypters* belong to the group of *Sauroids*, or *Lizard fishes*, proposed by Agassiz to include these, and many fossil *Ganoids*. They have all the essential characters of *Ganoid* fishes, and like the *Sturgeons*, are furnished with swim bladders communicating directly with the gullet or stomach, as in the *Le-*

pidosiren. The Lepidostids are represented in Fig. 157; they are elongated fishes, enclosed in strong ganoid scales, and are



Fig. 157.

confined to the waters of the United States and Canada; of these ten species have been described by Agassiz, by whom they are regarded as the nearest representatives now living of the extinct Ganoid fishes. The Polypters are an African family, found in the Nile, Senegal, and Niger, and they are no less illustrative of some of the extinct ganoids than the Lepidostids. In Fig. 158 is represented the Nilotic Polypter, called the *Gymnarch*, or *del-*

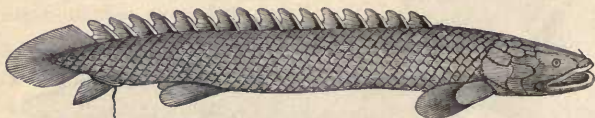


Fig. 158.

el-far by the Egyptians. It is elongate in form, and has the head protected, like that of the Sturgeon, by bony plates; the dorsal fin consists of an even row of detached finlets, each having a strong spine in front, followed by four or five soft branching rays. The Sauroid character of this fish is shown by the structure of its swim bladder, which consists of two sacks of different lengths, opening into a short common chamber, which communicates, by means of a long slit, furnished with a valve, with the ventral floor of the gullet; this swim bladder, serving the purpose of a double lung, is supplied with venous blood.

F. *Teleosteans*.—*Skeleton bony; spinal column composed of distinct vertebrae; gills free.* This group includes the great

majority of living fishes; they are characterised by the possession of a more perfectly ossified skeleton than the preceding groups, but seem to be inferior to some of them in other more important features of organisation. Their classification has puzzled naturalists exceedingly, and no satisfactory system has yet been proposed. The greater number of them may be readily placed under two heads, and arranged either by the structure of their fins, or of their scales:—

a. *Soft-finned fishes, or Cycloids.*

b. *Spine-finned fishes, or Ctenoids.*

The *Soft-finned* fishes have the rays that support the fins *jointed*, and mostly split towards the point (except sometimes the first ray of the dorsal or pectoral fins). This subdivision very nearly coincides with the *Cycloid* fishes of Agassiz, which are characterised by oval scales not serrated at the margin.

The *Spine-finned* fishes have the bony rays that support the anterior part of the dorsal and anal fins *without joints*, and mostly hard, strong, and pointed at the tip. They correspond with the *Ctenoids* of Agassiz, which are fishes characterised by scales furnished with fine spines or points along their posterior margin, giving a comb-like appearance to the edge of the scale.

The *Cod fish*, Fig. 151, is a good example of the soft-finned fishes, that have the ventral fins (hind legs) placed in front of the pectoral fins (fore legs).

In addition to the subdivisions of the bony fishes already named, naturalists are compelled to add the following, which do not readily come under either of the former:—

c. *Pleuronectoids*, fishes swimming on their sides.

d. *Lophobranchs*, cluster-gilled fishes.

e. *Plectognaths*, fishes with united jaws.

The *Pleuronectoids*, including *Soles*, *Turbots*, *Flounders*, and other so-called flat fish, are an aberrant group, characterised (Fig. 159) by an unsymmetrical head, with both eyes placed at one side;

they swim upon the side, and not upon the belly, the side that is down being white, while the uppermost side is coloured, to imitate the sand or mud frequented by these fish, so as to protect them from their numerous enemies, among which, probably, the most formidable is the Angel Shark, described already (Fig. 155). It has been ascertained that in the young flat fishes the

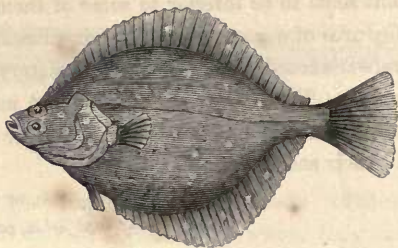


Fig. 159.

eyes are placed symmetrically, and that the young fish swims with belly down, like other fishes : as the animal grows, the bones of the head, in the neighbourhood of one eye, become altered, and actually allow the eye to pass round the head, so as to occupy an unsymmetrical position beside its fellow ; and while this singular process of growth goes on, the degraded fish learns to swim on his side, and leaving the free water, grovels on the sand or mud of the bottom, along which he creeps by a vermicular movement of his body and fins, quite different from the screw action of the tail, by which the higher fishes progress through the water.

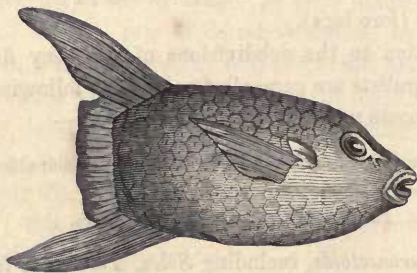


Fig. 160.

The *Lophobranchs* contain only a few small fishes, of which

the most striking is the little *Hippocampus*, found in the Mediterranean, and often on our own coasts.

The *Plectognaths* are met with chiefly in the Indian Ocean and South Pacific; they are remarkable for their peculiar teeth, and the singular appearance of their body, covered with polygonal scales or spines. The best known of these fishes are the *Sun fish*, the *Four-tooth*, and the *Coffer fish*. The *Oblong Sun fish* (*Molebut*) is shown in Fig. 160; it is occasionally caught off the coasts of Great Britain and Ireland.

CHAPTER VII.

INVERTEBRATE ANIMALS.

IN the preceding chapter we have given a brief account of the Vertebrate Animals, which possess in common a spinal column composed of distinct vertebræ articulating with each other, and enclosing a cord of nerve substance that regulates both sensation and volition. These animals, though differing widely from each other, are yet united by many resemblances, resulting from their common possession of a vertebral column and its enclosed cord of nerve substance. The Invertebrate Animals, which have now to be considered, agree only in a negative quality, viz., the *non*-possession of a vertebral column, and therefore, as we might expect, differ from each other much more profoundly than the different animals of the Vertebrates. The Invertebrates admit, however, of being subdivided, like the Vertebrates, into four groups, the members of each of which are constructed on a common type, and resemble each other, on the whole, more than they resemble the individuals of the other groups. These are—

1. Articulates.
2. Mollusks.
3. Radiates.
4. Protozoans.

1. **Articulates.**—The *Articulate*, or jointed animals, are also called *Annulose*, because their type of structure consists in a body, more or less elongated, and formed of a succession of rings, or segments, articulated together ; each ring or segment resem-

bles the others, is supplied with its own nervous ganglion, and may possess its own locomotive organs; thus the structure of the articulate or annulose animal is essentially repetitive—so much so, indeed, that in the lower forms of the class the animal may be divided into portions, each of which continues to grow and feed, like the uninjured animal. The *nervous* system in Articulates consists of two long cords ranged along the ventral surface, united at intervals by nodes or ganglions, each of which corresponds to a ring or segment of the body. The animal whose nervous system is shown in Fig. 161 is the *Mole cricket*; the first nerve ganglion supplies the eyes and antennæ, and is called the optic ganglion or brain; it lies in front of and above the œsophagus, which, ascending from the mouth on the under side of the head, always passes through the ring of nerve substance (called the *œsophageal collar*) shown between the first and second ganglions; the second nerve ganglion supplies the organs of hearing and taste, and the muscles of the jaws; and the fifth and tenth ganglions supply the place of the cervical and sacral plexuses of nerves in the Vertebrates. From the preceding description, we see at once the profound difference in the type of the Articulates and of the Vertebrate animals. In the Vertebrate Animals the intestinal tube and its appendages lie in front, not only of the spinal cord, but of the great sympathetic; whereas, in Articulate animals, the whole digestive canal lies behind the chain of ganglions, except the small portion between the mouth and the œsophageal collar of nerves; and the nervous cord lies along the ventral instead of the dorsal surface of the body.



Fig. 161.

The *Skin*, or body covering, in the Articulates is divided by transverse folds, or articulations, into a certain number of rings, the covering of which is sometimes shelly, and sometimes soft, but always has the muscles attached to its inner surface, as they are to the scales of the crocodile: many of these rings are provided with limbs, sometimes articulated, and sometimes not; or limbs may be entirely absent, in which case progression takes place as in the serpents.

The circulation of the blood in the higher articulates takes place in distinct vessels, and respiration is accomplished by means of organs especially devoted to the purpose.

The senses of taste and sight are the best developed, and some possess the sense of hearing; the jaws, when present, move laterally, and never vertically, as in the Vertebrates.

Digestion is variously effected in the different groups of Articulates; in the lower orders it is accomplished by means of a simple tube, in which one part cannot be distinguished from another; but in the higher classes, as *Insects*, the process of digestion seems to become as complicated as it is in *Birds*. In Fig. 162 is shown, on the scale of nature, the digestive tube of the *Mole cricket*. In this figure, *a* is the *oesophagus*, or gullet; *c* is the *crop*, or proventricle; *g* is the *gizzard*, or muscular stomach, furnished with two blind sacks, or *cæca*, at its pyloric orifice, which recall to mind the *pyloric appendages* of fishes; *ii* is the intestinal canal, not divisible into small and large intestines; and *k* is the tuft-like mass of tubes that represents the kidneys, opening by a common duct or *ureter* into the intestine.



Fig. 162.

2. Classification of Articulates.—The sub-kingdom of animals called articulate is composed of six classes, divided into two

groups, the *Arthropods* and the *Worms*; of which the former have jointed legs, and the others have either no legs at all, or simple bristles without joints.

Articulate Sub-Kingdom.

A. Insects.	}	Arthropods.
B. Myriapods.		
C. Arachnids.		
D. Crustaceans.		
E. Annelids.	}	Worms.
F. Scolecids.		

A. Insects.—This class of Articulates has the head distinct from the trunk, with sensitive antennæ; their respiration is performed by means of air canals distributed internally through the body, and divided into very fine branches. The first of these two characters distinguishes the Insects from the Arachnids, in which the head and thorax form a single piece, and which have non-sensitive antennæ; and the second distinguishes them from the Crustaceans, which possess gills, or other external appendages intended for breathing water. The Insects resemble the Myriapods in many particulars, but are distinguished from them by the lesser number of their ring segments, which in Insects never exceed twenty, while in the Myriapods they are always greater than that number. Five or six of the ring segments are combined, in Insects, to form the head; three or more of the segments are combined to form the thorax, to which three pairs of locomotive limbs, characteristic of perfect insects, are attached. Two additional pairs of locomotive organs (*wings*) are developed from the dorsal surfaces of the second and third thoracic segments, in most Insects.

The *antennæ* of insects are supposed by some to be the organs of *smell*, others believe them to be the organs of *touch*, and it has been asserted that they are the organs of *hearing*; they are unconnected with the mouth and are placed near the eyes, and they

derive their nerve filaments, like the eyes, from the anterior, or cerebral ganglion of the double nerve cord.

The *eyes* of insects are either simple or compound; the simple eyes being named *eyepoints*, and are like smooth shining points placed usually in a triangle behind the compound eyes, as in *Bees* and *Wasps*. The larger, or compound eyes, are formed by a large number of eye tubes, closely pressed together, so that each of them has become hexagonal; these are arranged on the sides of the head, on large convex surfaces which frequently, as in the *Dragon fly*, occupy the greater part of the head. These facettèd eyes have been frequently counted, and are often found to exceed 8000 in number, as in the *Fly* and *Cockchafer*.

The *mouth* of insects consists of six pieces; two placed vertically, at top and bottom, called the upper lip (*labrum*) and lower lip (*labium*); and two pairs placed horizontally, one above the other, opening and shutting horizontally, which are called *jaws*, the upper pair of jaws being named *mandibles*, and the lower pair, *maxillas*; the lower jaws are generally employed to hold the food while it is masticated by the upper pair.

The *heart* of insects has the form of a long pulsating arterial vessel terminating behind in a blind extremity, and lying above the intestines on the dorsal surface of the body; the hinder end of the heart is surrounded by a cavity containing venous blood, which may be regarded as performing the part of an auricle, and the blood is admitted into the heart by eight or nine pairs of lateral openings, closed with valves, which allow of the entrance of blood, but prevent its exit. The blood received into the heart through these lateral openings is pumped forwards by its pulse-like contraction, and distributed backwards through the body, following the track of the air canals.

The *air canals* of insects resemble the spiral vessels already described in plants, for they possess, between their outer and inner coats, a flat horny elastic thread coiled up spirally, which has the effect of keeping the canal always open. These canals

open externally on both sides of the thoracic and abdominal rings, by narrow slits called *stigmata*, but rarely by more than nine* pairs of such openings. The air canals divide and subdivide into smaller and smaller branches through all parts of the body of the insect, and are followed in their course by the ramifications of the arterial vessels, so that the blood of insects is oxidized, not in special organs, as lungs or gills, but in every part of the entire body. Many of the insects also that live in water really breathe by means of air taken from the water into their air canals, while their larvæ breathe the air in the water by means of gills; these latter have no stigmata or air slits.

Many insects undergo a three-fold transformation, in their growth from the egg to the perfect insect. On leaving the egg, the insect is called a *larva*, or caterpillar; it resembles a worm, has numerous pairs of legs, eats voraciously, grows rapidly, and often casts its skin, acquiring a new and larger skin to suit its rapid growth. After casting the skin for the last time, the animal assumes quite another shape, having a hard horny skin; it has no limbs, takes no food, and seems wrapt in a profound slumber; in this condition it is called a *pupa*. Important chemical and physiological changes, however, take place during the time (often many months) for which the insect exists in its pupa form; the stores of fat accumulated by the voracious larva gradually become absorbed and disappear; and the organs proper to the perfect insect are slowly elaborated. At last the perfect animal bursts its narrow cell, and emerges into day, when it is called the *imago*. At first the wings are short, moist, and unfit for flying, but they are soon unfolded and dried, and support in the air the full-grown insect, which fulfils the remaining duty of its short life—the propagation of its kind—and then dies.

* In the *Mole cricket* there are ten pairs, three in the thorax, and seven in the abdomen.

The following *Orders* of the class of insects are recognised by Naturalists :—

- a. *Apters*—Wingless.
- b. *Strepsipters*—Wings twisted.
- c. *Dipters*—Two-winged.
- d. *Hymenopters*—Wings membranous.
- e. *Lepidopters*—Scales on wings.
- f. *Neuropters*—Wings with strong netted veins.
- g. *Hemipters*—Half-winged.
- h. *Orthopters*—Straight-winged.
- i. *Coleopters*—Wings furnished with sheaths.

(a). *Apters*.—The *wingless insects* include three sub-orders, viz.,

- 1. *Thysanours*—Fringed tails.
- 2. *Parasites*—Parasites.
- 3. *Suctorians*—Suckers.

The *Thysanourans* are minute insects, *with six feet*, and *without wings*, *not undergoing metamorphosis*, *not parasitic*, *eyes simple*, *in two groups*; they are furnished with bristles at the end of their tail, which fold under the insect when at rest, and by their sudden straightening, the animal is thrown forward with a leap. Hence they are sometimes called *Springtails*. These insects present many analogies with the *Myriapods*, and the *Orthopters*, especially the *Earwigs*. The sub-order includes the *Sugar Lice* and the *Springtails*. The *Sugar Lice* were originally imported in sugar from America into Europe; with us they now generally live in books on damp shelves; they run rapidly and are covered with small silvery scales, which are used as tests for microscopes.

The *Parasites* are better known than loved; *they have six feet*, *no wings*, *are parasitic*, *and do not undergo metamorphosis*; *eyes one pair*, *simple*, *or none*. The Parasites include the *Lice*. The body of Parasites is flattened, semi-transparent, and contains eleven or twelve distinct segments; the stigmata of the air

canals are very large, and are shown in Fig. 163, which represents a view of the human louse under the microscope; the antennæ are short and composed of five segments; the legs are short and furnished with stout claws, by means of which these animals cling to the hairs of animals, or feathers of birds, whose blood they suck, and on whose body they propagate and pass their lives. Almost every mammal and bird is infested by one or more parasite insects, upwards of 500 varieties of which, modelled on the disgusting pattern of the human louse, Fig. 163,



Fig. 163.

have been figured and described. Man himself enjoys the privilege of possessing three such humble companions, named respectively by naturalists—

Pediculus corporis humanus—The Clothes Louse.

Pediculus capitis humanus—The Head Louse.

Phthirus pubis—The Crab Louse.

The fecundity of these brutes is fearful, and under specially favourable, but unknown conditions of the blood of their victim, their development becomes so excessive, that they seem, as it were, to pour from the body, and may be regarded as a symptom of serious disease. The term *morbus pediculosus* has been given to this terrible malady.

The Suctorians are better known by the name of *Fleas*. They are wingless, with six feet, and undergo perfect metamorphosis; mouth suctorial, having each maxilla furnished with two feelers stretching forward. The Suctorians are distinguished from the sucking Hemipters (*Bugs*), by their perfect metamorphosis, and by the presence of *palps* on the maxilla. In fleas there may be seen four minute scales, on the last two segments of the thorax, which are regarded as rudimentary wings. Different kinds of fleas infest different animals, whose blood they suck; and it is

said that although the dog flea will bite man, and the human flea will bite the dog, the change of diet disagrees with them, and they shortly die. The human flea (*pulex irritans*) lays about a dozen eggs in summer, in chinks of wooden floors, or furniture; these eggs are white, oblong, and sticky, and give birth to thin, wiry, active larvæ, after a lapse of six days; these little worms wriggle about like serpents, and roll themselves into flat spirals like that of Archimedes. They are provided by the foresight of their mother (herself taught by "Him who feeds the sparrows") with a nutritious and suitable food. Having selected suitable subjects among her human friends, she sucks their blood, and carries it to the place where she has laid her eggs; it is then disgorged from her gullet, and dries into a black globule, many of which are placed by the parent flea in the vicinity of her eggs; and these globules of human blood are observed to form the favourite food of the active little larva. After eleven days spent in the enjoyment of preserved blood, the larvæ having attained their full growth, spin themselves up, and change into pupæ, from which again, after ten or eleven days, the perfect imago emerges, both willing and able to change his diet of dried blood into the fresh-drawn blood of his human victims. Having once tasted this nectar, nothing will induce the flea to give up its pursuit; neither threats nor remonstrances are availing, and many millions of these little animals perish annually in their unequal contest with man. Their lively movements, however, and active disposition, win them the respect of their destroyer, who prefers their troublesome attacks, to the society of the hateful louse, and always gives them the boon of the Cyclops to Ulysses—that he will destroy them last.

Οὐτὶν ἐγὼ πύματον ἔδομαι μετὰ οἷς ἐτάροισιν,
Τοὺς δ' ἄλλους πρόσθεν· τὸ δέ τοι ξεινῆϊον ἔσται.

(b). *Strepsipters*.—These little insects, like those last described, are parasitic, and infest the *Bees*, and others of the *Hymen-*

opterous Order; they differ so much in structure from other insects, that they are placed in a separate order, the characters of which are as follows :—*Small insects with six feet; male furnished with four wings, of which the first pair are rudimentary only, and the second pair are large, membranous, and shaped like a quadrant of a circle, and are folded when at rest longitudinally like a fan; female without either feet or wings; metamorphosis complete. Larvæ and pupæ living parasitically in different kinds of Hymenopters. The males have compound eyes.* These minute insects, in their condition of larvæ and pupæ, were long known to infest the bee as parasites; but we owe the complete investigation of their metamorphosis, and of the differences of the sexes, to the observations of the Rev.

Mr. Kirby. A magnified view of the adult male is given in Fig. 164, which shows well the developement of the posterior pair of wings, and the compound faceted eyes of the bee-parasite called *Stylops*.



Fig. 164.

- (c.) *Dipters*.—These insects, like the last, have *only two wings*, but it is the *anterior pair of wings* that is developed, the *posterior pair being rudimentary*, and consisting each of a *thin pedicle, with a button at top*; these are called *poisers*; they have *six feet*, and a *suctorial mouth, formed of the labium produced into a proboscis*; their *metamorphosis is complete*; their *larvæ* are generally long lived, and have no feet; some of these *larvæ*, in passing into *pupæ*, do not change their skin, but the latter shrinks, hardens, and forms a *pupa case*, from which the larva separates and undergoes its transformation. Many of the *Dipters* attack man, and the domesticated animals, and suck their blood; others injure him by depositing their eggs on flesh and cheese, in which

their larvæ are developed, and on which they feed. They include the *Gnats*, *Horse Flies*, *Flesh Flies*, the *Tsetse*, and many others. The common House Fly (Fig.

165) will serve as a representative of the entire order. The larvæ of the common house fly live especially in horse dung, and are found only in the neighbourhood of human habitations; the larva is full grown in fourteen days, and in fourteen days more the



Fig. 165.

pupa produces the full-grown fly, while the egg requires only a single day (if the weather be warm) to produce the young maggot. Thus it happens that a whole generation of house flies may succeed another in a month's time; and in the meanwhile, the old stock of flies has not died off, for they live on until the frosts of early winter. Hence it is that the sudden increase of flies at the beginning of the autumn that follows a warm summer is readily explained. The reproduction of the *Flesh fly* (*Musca carnaria*) is still more rapid, and it has been estimated that the progeny of a single female of this species during one summer may amount to 500,000,000 of new flies. Naturalists have, in various ways, expressed their just astonishment at the power of destruction of carrion implied in such a wonderful fecundity; thus *Linnaeus* says, "that three flies could consume the body of a horse as quickly as a lion could;" and *Meigen* says, "that if Nature had not provided powerful counterplots for their destruction, these gentry would soon leave to Man so little flesh to eat, that fast days would become the fashion."

- (d.) *Hymenoptera*.—Insects with six feet, and four membranous wings; the second pair smaller, and having fewer veins; maxilla long, encasing the upper lip; tail of females almost always furnished with a sting; metamorphosis complete. This order of insects is distinguished by the possession of four membranous wings; it is separated from the Neuropters by its

wings possessing simple veins, and the second pair being smaller than the first pair; whereas, in the Neuropters, the veins are netted. Their nearest neighbours are the Dipters, and Aristotle first pointed out the distinction between the Hymenopters and the Dipters, by stating, that the Hymenopters have a sting in their tail, whereas the Dipters have a sting in their head, and the Coleopters have no sting at all. The Dipters, in fact, wound in order to feed, and the Hymenopters wound to defend or avenge themselves.

The Hymenopters include the *Gall Flies*, *Ants*, *Wasps*, *Bees*, and many other families; some of which are remarkable for their intelligence and instinct. The first, or cephalic ganglion, in these insects is unusually large, and the optic nerves are greatly developed; they possess, in addition to a pair of large compound facettèd eyes, three pairs of simple eyes. Many of these insects live together in families, and develop social instincts that have attracted the notice of observers from the earliest times.

We shall select as the best known example of the Hymenopters, the common *Honey Bee*. In England alone, upwards of 250 species of *Bees* have been described, all of which, including the Honey Bee, are originally natives of Asia and Europe; and some of them, including the Honey Bee, have been introduced by man into America. The Honey Bees are social, each hive containing from 15,000 to 20,000 individuals, of which 600 to 800 are *Drones* (males), one is the *Queen* (female), and all the others are *Workers* (neutral females). The relative sizes and forms of these three kinds of bees are shown in Fig. 166, in which *a* represents the Drone, *b* the Working Bee, and *c* the Queen. It is one of the disadvantages attending civilised society, that a division of labour not known in savage life becomes necessary, and this division of labour takes different forms in different kinds of society. Satirists have availed themselves of the arrangements arising from social combinations to draw comparisons between men and bees, not always to the ad-

vantage of the former; thus, the neutral workers are compared to our old maids, the power of the former residing in their tails,

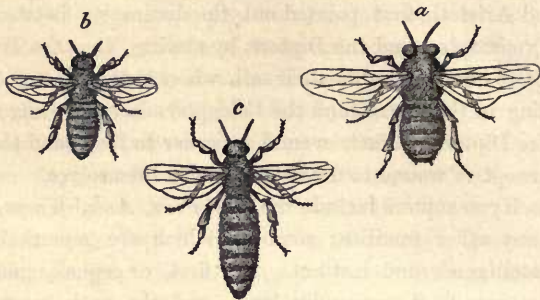


Fig. 166.

that of the latter, in their tongues; and the zeal of the working bees in providing food and lodging for the progeny of their more fortunate sister, the Queen, is contrasted with the grudging services rendered by our old maids to the children of their married sisters. Again, the bees put all the Drones to death as soon as they have fulfilled their duty, and are no longer useful; we, on the other hand, make Field Marshals of our Drones, and allow them to interfere in the affairs of State.

It has been ascertained that the Working bees are nothing else than imperfectly developed females, and that if the larvæ (which would naturally produce workers), be removed within three days after leaving the egg, to the larger royal cells, and there receive a more abundant and fluid nutriment, they will grow into fruitful bees, or Queens, instead of common working bees. The instincts, therefore, of the Workers are the instincts of females; the stronger of them go abroad in search of food, which they find in the nectaries of plants; and part of this honey food they convert into wax to form material for their cells, and part they store up in the cells that they have made; in the mean time, the weaker

of the working bees remain in the hive, look after the feeding of the larvæ, and attend to other domestic duties.

Ἦότε ἔθνεα εἰσι μελισσάων ἀδινάων,
Πέτρης ἐκ γλαφυρῆς αἰεὶ νίον ἐρχομένων·
Βοτρυδὸν δὲ πέτονται ἐπ' ἀνθισιν εἰαρινοῖσιν·
Αἱ μὲν τ' ἐνθα ἄλις πιποτῆται, αἱ δέ τε ἐνθα.

ILIAD.

“Qualis apes aestate novâ per florea rura
Exercet sub sole labor, quum gentis adultos
Educunt fetus, aut quum liquentia mella
Stipant et dulci distendunt nectare cellas,
Aut onera accipiunt venientum, aut agmine facto
Ignavum, fucos, pecus a præsepibus arcent;
Fervet opus redolentque thymo fragrantia mella.”

ÆNEID.

“For so work the honey Bees;
Creatures, that by a rule in nature teach
The art of order to a peopled kingdom.
They have a King, and officers of state;
Where some, like magistrates, correct at home;
Others, like merchants, venture trade abroad;
Others, like soldiers, armed in their stings,
Make boot upon the summer's velvet buds,
Which pillage they with merry march bring home
To the tent royal of their Emperor,
Who busied in his majesty, surveys
The singing mason building roofs of gold;
The civil citizens kneading up the honey;
The poor mechanic porters crowding in
Their heavy burdens at his narrow gate,
The sad-eyed Justice with his surly hum,
Delivering o'er to executors pale
The lazy yawning Drone.”

HENRY V.

The larvæ are hatched in three days, and five days afterwards they prepare to change, surrounding themselves with a fine web, on which they expend the labour of a day and a-half; in three

days they are converted into pupæ; the imago or perfect insect is produced from the pupa in eight days. The foregoing are the ordinary changes of the working bees; those of the Queens occupy a shorter time, and those of the Drones somewhat longer.

Many of the Wasps and Ants are social in their habits, like Bees, but their societies are more democratic. It may be worth while to describe briefly the political state of the three communities.

Among the Bees, one Queen only is recognised in the hive, and she is treated with the greatest attention by all the working Bees, each of whom visits her from time to time and satisfies herself of the Queen's presence in the hive, apparently by smelling her with the antennæ; if the workers be prevented occasionally examining the Queen with their antennæ, they take for granted that she is lost, and immediately proceed to manufacture a new Queen, as I have already described. If the Queen be removed from a hive, and a strange Queen introduced at once, she is surrounded by workers and kept a close prisoner until she dies of hunger; for the workers will never sting a Queen. If, however, some twenty hours have elapsed since the removal of their own Queen, the workers, instead of starving her to death, adopt her as their own, and admit her at once to the sovereignty of the hive, as if glad to escape the trouble of making a new Queen, by fattening a worker larva. When, however, a new Queen is introduced into a hive already in possession of a Queen, or when two young Queens emerge simultaneously from the royal pupa cases; each becomes surrounded by a crowd of workers, which prevent her escape, and the Queens are compelled to fight for the sovereignty of the hive. The workers look on with delight at the struggle for supremacy, without daring to interfere, or to aid either of the combatants; and, so far as man can judge the feelings of insects by his own, their emotions during the contest must resemble those of the curates of a diocese whose Bishoprick is vacant, who behold, with mingled feelings of terror and pleasure,

the fearful struggle for the empty Mitre, between two rival Dignitaries.

The *Wasps* are more democratic in their nature than the Bees, and yet they tolerate with composure the presence of numerous Queens in their society, many hundreds of these monarchs being found in a nest of wasps, at the close of summer; the reason of this extraordinary indifference to monarchical usurpation is to be found in the fact, that all the neutral or working wasps are destined to perish in the cold of winter, whereas their Queens will survive the winter and commence the battle of life in spring; now the wasps are philosophers, and know their fate, to which they resolve to submit with resignation, and they therefore enjoy, while they can, a jolly and roving life; they are freebooters, and attack fruits and flesh, on which they feast themselves; but, at the same time, as good fathers of families, mindful of the maxim of Voltaire, “*ces peres de famille sont capables de tout!*” they make it a point to attack plain working bees on their return from a hard day’s work; these they kill and rob, carrying home their honey, not for their own use, but to feed their larvæ with it. The association of robbers, called a wasp’s nest, owes its origin to a single mother Queen, who has survived the cold of the preceding winter; she builds her nest in spring, and lays her eggs in it, from which are produced the neutral wasps that are her first offspring; these furnish her with food, and help to make the new cells required by the increasing colony; and so they rob and plunder all around them, after the established custom of republics, and towards the end of autumn, close their eyes to the dangers that threaten the commonwealth, from the increase of young Queens, consoling themselves unconsciously with the reflection of the rascally statesman—“*Après moi le deluge.*”

The *Ants* are as sociable in their habits as the Bees, but are less easily observed; they are as democratic as the Wasps, but have studied political economy as well as liberty. The worker

ants are undeveloped females, like the corresponding class among Bees and Wasps, but they survive the cold of winter, and therefore, unlike the careless wasps, they have a future to look forward to and provide for : instead, therefore, of crowning a single Queen, like the Bees ; or allowing a multitude of Queens to grow up in the community, like the Wasps ; they take the most scrupulous care of the larvæ and pupæ belonging to the republic, airing them in the sunshine, and hurrying them below on the approach of rain ; but as soon as the imago insects are produced, they hasten to remove them from the nest, whether Drones or Queens ; and compel them to fly abroad in search of mates. Many of these thoughtless insects are devoured by birds, or drowned in water, and so made food for fishes ; the females, or Queens, that are left now divest themselves of their wings by means of their feet, and are ready to lay new eggs and found a new colony. The cunning workers readily recognise them by their want of wings, pounce upon any of them they can catch, and drag them to the nest, where they are compelled to lay their eggs ; when that is accomplished, the unhappy mothers are driven by the workers, without mercy, from the nest, and perish miserably, being starved, *secundum artem*, according to the maxims of political economy.

(e.) *Lepidoptera*.—*Insects with six feet ; and four membranous wings, covered with minute coloured scales ; mouth with involute spiral tongue, formed by the prolonged maxillæ ; metamorphosis complete.* These insects include the well known *Butterflies* and *Moths*. The scales that cover their wings seem like dust to the naked eye, but under the microscope appear arranged in regular rows, like house tiles or scales of fish. Their larvæ are called caterpillars, and consist of twelve rings, exclusive of the head ; they are furnished with nine pairs of air slits, for the second, third, and last ring have no slits. They have eight pairs of feet, the fourth, fifth, tenth, and eleventh rings having no feet. Most caterpillars live on

vegetable food, and many are confined to a single species of plant; others, however, especially of the *Moths*, eat leather, fur, fat, and wax. The Lepidoptera are divided into *nocturnal*, *crepuscular*, and *diurnal*.

The *Nocturnal Lepidoptera* are *Moths*; their wings are guarded by a part called the *retinaculum*, which consists of a horny elastic hair, arising on the anterior margin of the hind wings close to their insertion; a little flat ring on the under surface of the fore-wing allows it a passage, and thus both wings are connected, and so compelled to move together as one wing during flight. Their wings when at rest repose horizontally and not vertically, as in the *Butterflies*. The well known Silkworm moth, introduced into Europe in the time of the Emperor Justinian, belongs to the sub-division of Nocturnal Lepidoptera.

The *Crepuscular Lepidoptera*, called also *Sphinx Moths*, are



Fig. 167.

distinguished from the moths by the form of their antennæ; which in the nocturnal Lepidoptera are shaped like hairs or bristles, tapering from the base to the point; while in the crepuscular Lepidoptera, the antennæ are club-shaped, increasing in size from the base to the point. Their pupæ are never angular, like those of the Butterflies, but are generally smooth, and sometimes furnished with small spines. The *Death's Head Hawk Moth* (*Sphinx atropos*) Fig. 167 (so called from the death's head

and crossed bones marked upon his back) is one of the largest of European Lepidopters; it measures five inches across the wings; its larva is of a greenish yellow colour speckled with black, and measures, when fully grown, five inches in length; it feeds upon the potato plant and the jasmine, and buries itself in the ground before becoming a pupa. It is produced in this country, in hot summers, about the beginning of October, and its appearance in large numbers is much dreaded by the country people in the South of Ireland, and in Brittany; partly because of the ill-omened mark upon the insect's back; partly because of its feeble croak, that resembles the squeak of a sick mouse; but chiefly because the hot summer, that produces this Moth in abundance, has been often followed in the West of Europe by the outbreak of deadly epidemics.

The *Diurnal Lepidopters*, well known as *Butterflies*, have the wings mostly erect when at rest, and never bridled by a retinaculum. Their caterpillars always have eight pairs of feet; and their *chrysalis* is almost always naked, angular, attached posteriorly by threads, or suspended vertically, or affixed by a transverse silken cord expanded above the middle of the body; the Butterflies have club-shaped antennæ, often terminated abruptly by a knob.

(f.) *Neuropters*.—*Insects with six feet; four wings, membranous, transparent, reticulate, nearly equal; metamorphosis frequently incomplete; larvæ with six feet.* The veins, or nerves of the wings are reticulated, and the hind wings are usually as large as the fore wings; they are distinguished from the Hymenopters by their females having no sting. Most of the larvæ of the Neuropters are aquatic; and many of the fully developed insects display much instinct, as the *Ant lion* and *Termite*. This order of insects includes the *Caddis worm*, the *Dragon flies*, and the *May flies*, the *Ant lions*, the *Termite Ants*, and others.

The *Caddis worm* and *May flies* are well known to the

angler, and are usually placed among the Neuropters, although their wings cannot be considered as reticulated. The *Cad bait* is the larva of the *Caddis fly*, and lives in the water, in cases made artificially of bits of sticks, grains of sand, small shells, and other substances, which are held together by silken threads secreted by the worm itself; these cases serve as a protection to the larva during its early life. The *May flies*, also called Ephemerals, because they live in the imago state only for a single day, spend years in the larva condition, in wet places or altogether under water; the *nymphs*, like the larvæ, live at the bottom of the water, between stones, or in the ooze; and the change from the nymph to the imago is so sudden, that there is almost, at the same moment, a creeping and a flying insect. At the close of May, particularly on its last three days, there takes place what is called "the dance of the May flies," when these little creatures, produced to exist for twenty hours, enjoy their happy dance, and seem as difficult to count as the flakes of falling snow in winter; this dance is performed mostly over running water, and is watched with interest by many species of fish, especially the roach, which feasts itself and grows very fat on the bodies of the little dancers. Their bodies are collected in Carniola, and in the neighbourhood of Lough Neagh in Ireland, as manure for land. The great Linnæus has thus celebrated the history of the May flies:

"Ephemeræ larvæ natant in aquis; volatiles factæ fruuntur gaudio, uno sæpe eodemque die, nuptias, puerperia, et exsequias celebrantes."

The *Dragon flies* (Fig. 168), are among the most active and voracious of insects; as larvæ, as pupæ, and as flies, they are greedy and strong; they have very large faceted compound eyes, and also three simple eyes. In the larva state they are aquatic, and engaged in unceasing war with other insects; their pupa condition also is one of activity and is passed under water; they are in this state furnished with a sort of mask formed out of the

lower lip (*labium*) with which they cover their jaws; and they use this curious mask in order to alarm and seize their prey,

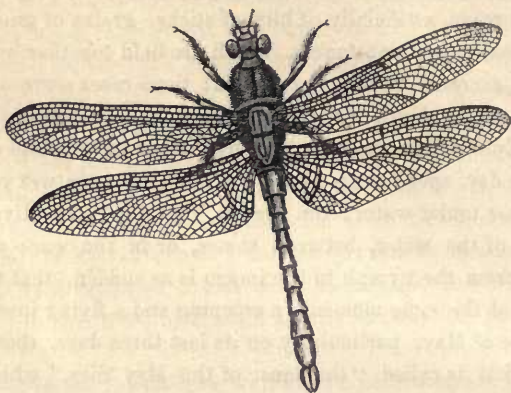


Fig. 168.

projecting and retracting it at will. In the imago state they are so ferocious, that they have been known to attack and devour their own bodies!

The *Lion Ant* and the *Termite Ant* are foreigners, but are well known from the descriptions of travellers. The larva of the *Lion Ant* is celebrated for its cunning; it has six feet, very large upper jaws (*mandibles*), and a flat head, with oval abdomen. This animal digs a hole in sand, of a funnel shape, the sides of the cone necessarily lying at the angle of repose, so that an incautious insect, coming to the edge, must slip down to the bottom, where the *Ant lion* lies buried in the sand, and immediately grips his victim with his powerful forceps, and devours him without mercy.

The *Termites*, or *White Ants*, are social insects, and are even more complicated in their economy than in the social Hymenopters. They live principally in warm countries, where they cause infinite damage. They leave the surface of the woodwork or

furniture attacked by them untouched, so that everything preserves externally its usual appearance, but falls to pieces on the slightest touch ; glass, metal, and stone alone escape their ravages.



Fig. 169.

In Guinea and other parts of Africa they build conical mounds, twelve feet in height ; in the centre of the mound is placed the residence of the Queen, and round the royal residence are ranged the royal cells, magazines for food, and other conveniences. The Termite Queen (Fig. 169) is the most fertile of insects, and is capable of laying 80,000 eggs at a sitting. The males have wings, and seem to be guarded by the workers as carefully as the Queen. Of the neutral, or undeveloped Termites, there are two distinct kinds, one called *workers*, and the other called *soldiers* ; the duty of the former is the same as that of working bees and wasps, while the duty of the latter is altogether defensive, and they are furnished for the efficient discharge of this duty with a pair of powerful pincer jaws.

(g.) *Hemipters*.—These are *insects with six feet ; with four wings, all membranous, or the fore wings leathery at the base, and membranous at the tip* ; their mouth consists of a sucker, formed from the lower lip (*labium*), and composed of threads and a case enclosing them ; this case is tubular, grooved above, and consists of joints. This beak is constructed for sucking ; the fine threads (*setæ*) enclosed in the grooved lower lip make a wound in the parts of animals or plants, on whose blood or juices they feed, the fluid ascending between the piercing threads, by means of the grooved *labium* into the œsophagus above. Their metamorphosis is incomplete, with

a few exceptions. The Hemipters are generally subdivided into two groups, called *Homopters* and *Heteropters*, to the latter of which only the term Hemipterous strictly belongs.

The *Homopters* have the fore wings altogether membranous as well as the hind wings; and their beak arises from the inferior part of the head, and is bent down beneath the breast between the feet. The Homopters include the *Plant Bugs*, the *Plant Lice*, the *Cicadae*, and the *Lantern flies*.

The *Heteropters* have their fore wings leathery at the base, and membranous at the tip; their beak is frontal, arising from the fore part of the head. They contain *Water Bugs*, and *Land Bugs*, and are all characterized by a disagreeable smell caused by a fluid that escapes through two apertures, placed one at each side below the thorax, at the insertion of the third pair of feet.

The *Plant Bugs* live upon the juices of various plants; they are of small size, and in the larva state have the appearance of oval scales, and remain closely adherent to the leaf or bark of the tree to which they have attached themselves; they undergo their transformation into the pupa stage without changing their skin. The female is wingless, and when about to lay her eggs, assumes a hemispherical form, instead of the flat circular disk-like shape she had before. Many of the foreign plant bugs have been long celebrated for the beautiful dyes they yield. One of the most celebrated of these insects is the *Coccus ilicis* of the South of Europe, formerly used as a medicine, but now employed only as a dye; it was called *kermes* by the Arabians (from which term our word *crimson* is derived), and was largely employed to furnish a red dye, until the introduction of the *Cochineal* insect from Mexico, in 1526, destroyed its commercial value. The *Cochineal* insect (*Coccus cacti*)

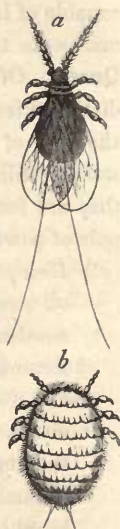


Fig. 170.

has a female of a deep brown colour, covered with a white powder, with transverse incisions on the body (Fig. 170 *b*); the male is of a deep red colour, and has two white wings (Fig. 170 *a*). It is computed that it takes 70,000 dried bodies of the cochineal insect to form one pound of Cochineal; and that 880,000 lbs. of this dye are annually imported into Europe. The *shell lac*, *lac varnish*, and *lac dye* of the East Indies, are produced from a kind of plant bug that feeds on the juice of different kinds of figs (*Coccus ficus*).

The *Plant lice* or *Aphides* are among the most remarkable of insects; they live together in great numbers on different plants and trees, and move very slowly in consequence of the great length of their legs; they are generally of a green colour, but are sometimes black; from the hind part of the abdomen there drops a transparent honey-sweet fluid of which ants are very fond, and to procure which they follow the aphides. The reproduction of plant lice is very remarkable; they are viviparous, or rather *larviparous*, each of the larvæ produced by the common mother being a female capable of producing other females, and so on to the seventh, ninth, or eleventh generation (according to the species of *Aphis*); it is only among the larvæ produced by the last generation of females that the male insects begin to appear; the male and female *Aphides* produced by the last generation acquire a more perfect developement than the preceding generations, for both males and females possess wings, whereas the preceding generations were altogether composed of wingless females. The perfect winged males and females of the last generation unite in autumn, after which the males die off, and leave the fertilised females to produce anew in spring, their daughters, and granddaughters to the eleventh generation. Reaumur has found that each of the female aphides lays twenty-five female larvæ each day, and has calculated that the old grandmother *Aphis* may often live to see 5,904,900,000 of her posterity! The wonderful fecundity of plant lice becomes often a question of national importance, for the entire crop of hops and of beans has been often destroyed by

these minute but numerous parasites. It is generally believed that a delicate condition of the plant itself is necessary to the developement of large numbers of the plant louse, just as the *morbus pediculosus* in man is regarded by physicians as a sign of disease quite independent of the parasite.

The *Treehoppers* and *Cicadæ* are closely related to each other, the former being dumb and furnished with saltatory feet; while the males of the *Cicadæ* are furnished with two membranes, placed one at each side of the base of the abdomen, by causing the vibrations of which, they are able to give out a high clear note. These are found in warm countries only, while the *Treehoppers* are common everywhere. The best account we possess of the transformations of the *Cicada* is that given by Aristotle, who says :—"The *Cicadæ* deposit their ova in the fields, piercing the soil with the ovipositor placed at the end of the body, like the *Locusts*; they oviposit also in the reeds that are used to support the vines, these they pierce; and so they do in the stems of the squill; the young ones are washed into the earth and are common in rainy weather. The maggot, when it has grown in the earth, becomes the *matrix cicada* (*pupa*) called τεττιγομήτρα. When the season arrives for their appearance, about the Solstice, they come forth by night, and immediately burst their envelope, and the *matrix cicada* becomes the *cicada*. They immediately become black and hard, acquire their full size, and the males begin to sing."

The sweet continuous song of the *Cicadæ* was much praised by the Greeks, who regarded them as favourites of the muses living on dew at the summits of high trees, heralding the approach of joyful summer with their sweet notes, and resembling the happy gods. Homer compares the Trojan Ancients collected round Priam, on the walls of Troy, to the *Cicadæ*, whose song was as sweet and pure in sound as the lily is in colour :—

. τεττίγεσσιν εοικότες, οἳ τε καθ' ὕλην
Δενδρέφ' ἐφεζόμενοι ὅπα λειριόεσσαν ἰεῖσιν.

The *Water Bugs* abound in fresh water, and are well known by the names of *water runners*, *water boatmen*, *water scorpions*; the water boatmen are particularly interesting, and may readily be seen in any stagnant pool in summer, coming to the surface in search of insects that may have fallen into the water, and on whom they feed; they swim upon their backs, using as oars the third pair of feet, which are developed into swimming organs.

The *Land Bugs* are, unfortunately, only too well known to us, by means of the Bed bug. This disgusting creature is two and a half lines long, wingless, brown red, with short felty hairs, head small, thorax broad and short; it is able to live without food, enclosed in glass, for an entire year, and is not killed by the severest frost, but immediately revives from its torpor on the first warmth. In Russia, where, from the extreme cold, the bed bugs are torpid during the winter, they become exceedingly fierce in spring, and it is a common joke at this season to complain to the landlord of the country inn, that you heard the bugs barking at you in the night.

(h.) *Orthopters*. *Insects with six feet; four wings, the fore wings forming leathery sheaths, and the hind wings being folded radiately like a fan; mouth suited to mastication, and furnished with strong mandibles.* All the Orthopters are terrestrial; some are carnivorous or omnivorous, but most of them feed on plants, to which they are, in certain years, very destructive. They include *Locusts*, *Crickets*, *Earwigs*, *Cockroaches*, and the curious insects called *Walking leaves*. The Orthopters are divided into two groups, viz.: the *jumping* and the *running* Orthopters; the former also produce a chirping sound, and the latter are dumb. The sound is produced by drawing the thighs of the hind legs quickly across the wing sheath, which is thus set in vibration, and in some species the sound is increased by the resonance of a drum-like membrane placed at both sides of the first abdominal ring. The chirping sound thus produced has a very

high pitch, so that some persons cannot perceive it; and its production is confined, as in the *Cicadæ*, to the males; for which reason Xenarchus praises the *Cicadæ* as being more happy than men, because their wives are dumb.

The general form of the jumping Orthopters is shown in Fig. 171, representing the *Grasshopper*, or *Locust*, of the East, which occasionally visits this country in hot summers, and has



Fig. 171.

been from time immemorial the plague of Africa and Syria; it is stated by trustworthy travellers that a space of nearly 2000 square miles, in the southern parts of Africa, is often covered by a swarm of locusts; in this part of the globe, when driven into the sea by a north-west wind, they form upon the shore for fifty miles a bank four feet high, the stench of which can be smelt 150 miles inland, when the wind comes round to the south-east.

The *Walking leaves* are in great part confined to tropical countries, and many of them are found in New Holland; they live on vegetable food; some, without wings, having the appearance of dried twigs; others, which are flat, with membranous and veined wing covers, have a great resemblance to the leaves of plants (Fig. 172).

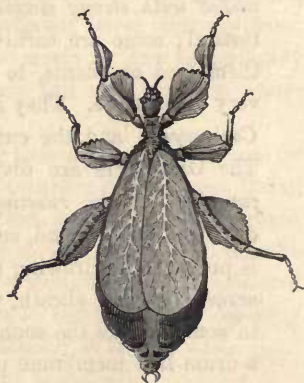


Fig. 172.

The *Cockroaches*, or *Kakerlacs*, are well known for their voracity

and nocturnal habits. The *Cockroach* will eat leather, paper, and almost every organic substance. The male has wings extending only half the length of the body, and the female has only rudimentary wings; her eggs, which are about sixteen in number, are deposited in an oblong cylindrical case, which she carries about with her, fixed to her abdomen; from this case the young larvæ escape, by emitting a fluid that dissolves the case.

The *Earwigs* are so called from their habit of creeping into the ears of those that are foolish enough to sleep on the grass in summer; they live in moist places, and are characterised by having the last ring of the abdomen armed with a pair of forked moveable forceps; they are fond of fruits and honey; and the female sits on her eggs and guards them; the young also creep under their mother, like chickens under the hen, and she often sits quietly over them for hours together. The wings of our garden Earwig are transparent, of large size, and shaded like a fan; when not in use, they are folded under two horny wing-cases, so that the insect appears to be destitute of wings.

(i.) *Coleopters*.—*Insects with six feet; with four wings, the fore-pair hard, leathery, and partially covering the hind wings, which are membranous, and folded transversely, in order to be covered by the first pair, called elytra; mouth formed for chewing; metamorphosis complete.* Upwards of 30,000 kinds of *Coleopters*, or *Beetles*, are known, and they were first formed into a division of insects by Aristotle, who gave them the name of *Coleopters* (κολεόπτερα). The *Beetles* are in general remarkable for the hardness of their skin, and the metallic brilliancy of their colours; and many of them are highly voracious, and carnivorous.

It would be impossible, in an elementary work, to give a description of the several families into which the 30,000 or 40,000 *Beetles* known to science are divided, and I shall therefore content myself with the description of a few, that are either respectable from the antiquity of the naturalists

that observed them, or remarkable for their own qualities.

The *Dung Beetles* of the ancients, so called from their dirty habit of rolling the excrement of various animals into balls for the purpose of depositing in them their eggs, belong to the family called *Lamellicorn Beetles* by the moderns. Linnæus divided the *Lamellicorns* into two genera, *Lucanus* and *Scarabæus*, the latter of which words is the Latin corruption of *κάραβος*, the *Stag Beetle*. The Beetles called *Scarabæus* by Linnæus are now reckoned to be 3000 in number, and are characterized principally by the structure of their antennæ.

The *Dung Beetles*, properly so called, form one of the six sections into which the Linnæan genus *Scarabæus* has been divided; and unquestionably the most celebrated of these Beetles is the *Sacred Scarabæus* of the Egyptians (Fig. 173). This brute is one inch in length, and of a jet black colour; it is found in France, Spain, and Italy, as well as in Egypt, and must have been well known to the Greeks from the accurate description of its habits given by the Comedian Aristophanes. It encloses its eggs in a ball of excrement, which it forms by rolling the nasty substances between its legs, or as Aristophanes says:—



Fig 173.

See how the cursed devil eats, bending himself
Like a wrestler, and laying on with his grinders,
Going at it with his head and paws;
Like sailors twisting the strong ropes for ships.*

* οἷον δὲ κύψας ὁ κατάρματος ἰσθίει
ὥσπερ παλαιστής, παραβαλὼν τοὺς γομφίους·
καὶ ταῦτα τὴν κεφαλὴν τε καὶ τῷ χεῖρὲ πως
ὥδι περιάγων, ὥσπερ οἱ τὰ σχοινία
τὰ παχέα συμβάλλοντες εἰς τὰς ὀλκάδας.

Some modern naturalists insist that the *Scarabæus* uses only his hind legs in rolling the ball in which it lays its eggs, and that it never eats the choice food prepared for its larvæ; but I prefer the testimony of Aristophanes, who distinctly states that this Etnæan Beetle uses its fore paws and head in rolling the ball, and that it levies its own tithe of the commodity until its breath stinks of it. The size of the ball, when completed, is much larger than that of the Beetle, being sometimes as much as $1\frac{1}{2}$ inch in diameter. This strange Beetle, called *κάνθαρος* by the Greeks, was worshipped as sacred (*Scarabæus sacer*) by the Egyptians, who regarded it as a symbol of the power that rules the world, because it rolls a globe before it; it is figured on the monuments of their dead, and imitated in different kinds of stone as ornaments for their women, and for amulets.

The *Glow-worms*, of which the male and female are shown in Fig. 174 (*a* and *b*), are Beetles, of which the males have wings and the females are wingless. They diffuse a phosphoric light at night, which is supposed to proceed from the neighbourhood of the internal genital organs; the males shine less than the females, and cease to do so after pairing, whereas the females are most luminous while engaged in laying eggs. This light becomes dull in carbonic acid and hydrogen gases, and is stronger in oxygen gas. Its use, if it have a use, is quite unknown.

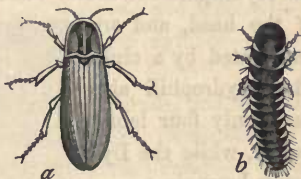


Fig. 174.

The *Water Beetles* (*Dyticidæ* and *Hydrophili*) are very variable in size, some being very minute, while others are several inches in length; their four hind legs are larger than the fore legs, flattened and hairy; they can swim well, not like the Water Bugs, on their backs, but their bellies, and at the same time can fly rapidly through the air. The *Dyticidæ* live in fresh water,

and are very voracious, chasing other water insects and capturing them with their fore feet, which are not used in swimming. Although they can remain for a long time under water, they are obliged to rise occasionally for air; this they do by remaining quiet, when their bodies rise to the surface obliquely, with the head downwards (Fig. 175), so that the extremity of the abdomen, on which the air slits are placed, becomes exposed on reaching the surface.

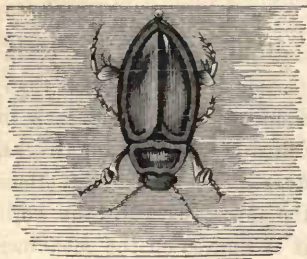


Fig. 175.

The *Hydrophili*, or large Water Beetles, are very different from the *Dyticidæ*. One of these, nearly two inches in length, is shown in Fig. 176; it is pitchy black, with antennæ and feelers red brown. It may be distinguished from the *Dyticus* either by its antennæ or by its habits. The antennæ of the *Dyticidæ* are longer than the head, bristle-shaped, and have eleven joints; whereas the antennæ of the *Hydrophili* are short, inserted in a deep fold under the side of the head, and are terminated by a club. The *Hydrophili* also have only four labial feelers, while the *Dyticidæ* have six.



Fig. 176.

The *Hydrophili*, moreover, breathe quite differently from the *Dyticidæ*: when they feel the necessity for fresh air, they rise to the surface, with the head upwards instead of downwards, and cover the abdomen

with a stratum of air by means of the antennæ; this provision of air for breathing shines under water like silver, in consequence of the total reflexion of light from its surface. The thorax of the Hydrophili is terminated by a sharp spine, between the hind legs, which often hurts those that handle them incautiously.

B. *Myriapods*.—These articulates have respiratory organs formed of air canals like those of Insects, from which they are distinguished by having always more than twenty rings in the body; their feet are numerous (twenty-four or more), disposed along the whole body, and each terminated by a single claw; the head is distinct from the thorax, but there is no well-marked division between the thorax and abdomen; they must be regarded as inferior in organisation to perfect six-footed insects, but they show many resemblances to the larvæ of these animals. They resemble Worms in their mode of growth, for in early life they have few rings, and only three pairs of feet; but as they grow, new rings are formed, and the number of feet is increased. Many of the Myriapods are characterised by having two clusters of single eyes, the number of which, like that of the rings of the body, increases with their developement. The Myriapods are usually divided into two sections—the *Centipedes* and *Millepedes*—so named roughly from the greater or lesser number of their feet.

(a). *Centipedes*.—These Myriapods are carnivorous, and have the second pair of feet furnished with pincers, terminated by a strong hook, which is perforate, and gives passage to a poisonous secretion. The body is depressed, covered above and below with horny plates, and membranous at the sides; their feet are lateral, generally a single pair to each body ring, the posterior feet being the longest and extended backwards. These animals are very active, and can run and turn the body very quickly, so as to creep into curved passages in pursuit of their insect prey. The *Scolopendra* (Fig. 177) is the largest and most dangerous of the Myriapods,

often reaching in South America a length of fourteen inches, and one and a quarter inch across the body; it has, generally, twenty-one pairs of feet behind the clawed feet; and is



Fig. 177.

furnished with four single eyes at each side of the head, behind the base of the antennæ, which have from seventeen to twenty joints. The *Scolopendra gigas* is much dreaded in South America, where it often takes refuge in furniture and beds; but its bite has very rarely proved fatal to man.

- (b.) *Millepedes*.—These Myriapods are easily known from the Centipedes, by their round worm-like body, and greater number of feet, which gives their motion a slow vermicular appearance; also their antennæ are short, and contain only six or seven joints, instead of the fourteen to forty found among the Centipedes. They are innocent little animals, and live chiefly on vegetable food, while some eat also dead earthworms and small mollusks. Many of them diffuse a disagreeable odour, caused by a greasy fluid that is excreted from a small sack placed in each body ring, and at each side. The little garden Millepede (*Julus*) is shown in Fig.

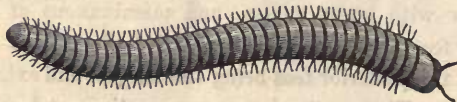


Fig. 178.

178; it rolls itself up spirally with the head in the middle, and the numerous delicate little feet placed inside, so that it

is comparatively protected, and in this posture it passes the winter. The eggs are deposited in spring by the female, who lays sixty or seventy in a hole prepared in the ground, and after three weeks the young make their appearance, without legs; after a short time they acquire three pairs, and afterwards additional rings and pairs of feet are developed in the part of the body placed in front of the penultimate ring.

C. *Arachnids*.—*Articulates with jointed feet; head and chest united into a cephalothorax; feet eight in number, not abdominal; circulation performed by dorsal pulsating vessel; respiration various*.—The Arachnids include *Spiders, Scorpions, Mites, and Sea Spiders*.

(a.) *Spiders*.—*Feelers thread-like; abdomen covered with a soft skin, joined to the cephalo-thorax by a stalk; air slits two or four, opening into lungs*.—These well-known animals spin silky filaments, from which they prepare their webs and nets, and with which they always cover their eggs. These threads are formed by four or six spinnerets, placed at the hinder end of the body, from which the silky threads are drawn out through fine tubes. *Spiders* are furnished with single-fingered mandibles, having a perforate terminal claw, for the discharge of a poisonous excretion; their feet are of different lengths, but similar in form, and each terminated by a double or triple claw.

The habits of *Spiders* are very various, and, accordingly, they have been divided into the following groups:—

1. *Hunting Spiders.*
2. *Wandering Spiders.*
3. *Prowling Spiders.*
4. *Spinning sedentary Spiders.*
5. *Swimming Spiders.*

The *hunting Spiders* have the habits of Wasps, and spend

their time incessantly running or leaping about the vicinity of their natural abode, to chase and catch their prey.

The *wandering* or *vagabond* Spiders are real *tramps*, and have no fixed homes; they take long journeys, without caring to return, in search of food; and only stay for any length of time in the same place when about to deposit their eggs.

The *prowling* Spiders form threads and nets to catch their prey, but do not sit in the web they have made; they prefer to prowl about in its neighbourhood, returning to it from time to time, like fishermen that have set long lines, which they return at intervals to examine.

The *sedentary spinning* Spiders are those best known to the generality of observers; they always live either in the middle or at the side of their symmetrical web, to be in readiness to attack the insects entangled in it. They are considered to resemble chamber lawyers, while the other Spiders are more like attorneys.

The *swimming* Spiders live in water, and there form a bell-shaped waterproof web, filled with air, and open below; this web is fastened by them to water plants by slender threads. These Spiders breathe air exclusively, and carry it about their persons, like the Hydrophilous Beetles.

(b.) *Scorpions*. The Scorpions have *large feelers (not antennæ) resembling feet, with pincers; abdomen divided into segments; and breathe by four or eight pulmonary sacks.*—They live in warm regions of the temperate zone, and in tropical countries. They possess a poison gland in the last joint of their tail, which renders their wound somewhat dangerous. Their body is composed of twenty rings, of which six are allotted to the head; and the last five segments of the body are narrowed into a tail. They lurk under stones in the neighbourhood of old buildings, and sometimes enter dwelling-houses; they run about quickly, brandishing their tails over their backs, and are thus more readily seen and avoided than the *Scolopendræ*.

(c.) *Mites*, or *Acari*; have the cephalothorax united with the abdomen, which is not divided into segments; mandibles forceps-shaped; eyes none; feet terminated by an adhesive cup and by a claw.—These are well-known little animals, many of them being parasitic; they all breathe, like insects, by means of air canals; and many of them live in cheese and other provisions, in which situation they multiply exceedingly. A species of Mite that digs into the flesh of Scotchmen is called the *Sarcoptes Scabiei*, and produces the “*Itch*”; other varieties are connected with the rare disease called “*plica Polonica*,” which is now becoming fashionable in Western Europe since the introduction of “*Chignons*.” Similar animals are found in the horse and in mangy dogs.

(d.) *Sea Spiders*.—These, as their name implies, are wholly marine, and on this account were long supposed to be Crustaceans. They have no organs of respiration. Like the true spiders, they are provided with eight legs, which in some species attain an extraordinary length, and include cæcal prolongations of the stomach.



Fig. 179.

D. *Crustaceans*.—The Crustaceans are articulate animals, without wings; having jointed feet, both thoracic and abdominal; breathing mostly by gills, but sometimes by the skin, without air slits; heart often distinct, aortic, and dorsal. The circulation of blood in the higher Crustaceans is effected, as in the higher Mollusks, by means of an arterial heart, and not, as in the Fishes (Fig. 152), by a venous heart. The heart is dorsal, and gives off arteries to the eyes and antennæ, to the liver, and to the intestines and genital organs; the blood, distributed to these various organs, returns through the gills to the heart, having become oxidised in

those organs (Fig. 179); whereas in Fishes (Fig. 152) it is first distributed to the gills, and thence forwarded to the various parts of the body.

The Crustaceans are divided into the following Orders, exclusive of some that are only found Fossil:—

- a. Podophthalms*, or Stalk-eyed Crustaceans.
- b. Hedriophthalms*, or Sessile-eyed Crustaceans.
- c. Entomostracans*, Crustaceans with shells.
- d. Cirripedes*, Crustaceans with curled feet.
- e. Xiphurids*, Crustaceans with tails like swords.

(*a.*) *Stalk-eyed Crustaceans*, or *Podophthalms*; have eyes which are compound, placed on the extremity of two moveable stalks; four antennæ. The Stalk-eyed Crustaceans include two well-marked groups—

- 1. *Decapods*, . . . Ten-footed Crustaceans.
- 2. *Stomapods*, . . . Crustaceans having the mouth between the feet.

The *Decapods* have a large shield covering the head, and thorax, and anterior part of the abdomen; their gills adhere to the bases of the posterior maxilliform feet, and are pyramidal, and covered by the shield: their feet are mostly in five pairs, but are sometimes in six pairs. The Decapods are usually divided into the following groups:—

- Long tails*, . . . Lobsters, and Shrimps, and Cray fish.
- Short tails*, . . . Crabs.
- Anomalous tails*, Hermits.

The *Lobsters* are characterised by their first pair of fore feet being converted into large grasping forceps, while the second and third pair are provided with smaller forceps; the tail is formed of a number of plates arranged transversely.

The *Shrimps* have the first pair of feet thicker than the other four pairs, and two-fingered, with the inner finger very short and immoveable.

The *Cray fish* (*Palinurus*) have no forceps on any of their feet; they are large Crustaceans which inhabit rocky places in

various seas, and are found in abundance in the Mediterranean, where they sometimes attain a length of three feet. This Crustacean is described by Aristotle, under the name of *κάραβος*, as the type of its class; it appears to be entitled to this distinction, both on account of its large size, and also on account of the fact, that it readily kills the Lobster, although it is not furnished, like that Crustacean, with a forceps claw, with which to attack its enemy.

The *Short-tailed Crabs* have the tail, or posterior part of the abdomen small, and reflected forwards, while the shield covering the thorax is proportionately very large; the first pair of feet is always provided with a forceps, and is sometimes very large, as in the Lobsters.

The *Hermits* have the abdomen contorted and membranous, and endeavour to protect it by seeking refuge in dead univalves (*Trochus*, *Natica*, &c.), which they carry along the shore upon their backs; like the common crabs, they are furnished with pincers upon the first pair of feet, but have the fourth and fifth pair of feet undeveloped. These animals seize upon empty shells of different gasteropods, as they grow older, and when fully grown, are generally found, on our coasts, in the shells of the large whelk (*Buccinum undatum*). The ordinary forms of crabs, lobsters, shrimps, and cray fish, are so well known, as not to require illustration, and I have therefore selected, in preference, one of the Hermit or Soldier crabs, extracted from his artificial house (Fig. 180.)



Fig. 180.

Stomapods are much less known than Decapods; they are distinguished from them by the tendency to form a larger number of pairs of feet (often six, seven, or eight pairs), and by their gills being always *uncovered*, and often attached to the *caudal* feet;

their shell also is thin or membranous, instead of being very hard, as in most of the Decapods. In some of the Stomapods there occurs an extraordinary development of the head and of the tail; the segment containing the eyes, with their nerve ganglion, being projected forwards in advance of the rest of the head and thorax. This

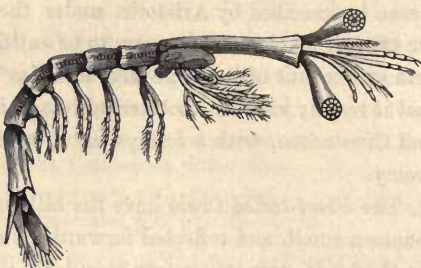


Fig. 181.

peculiarity of the Stomapod Crustaceans is well illustrated by Fig. 181, which shows the *Long-headed Shrimp* (*Lucifer typus*), first described by Mr. Thompson. The Stomapods are all swimming Crustaceans.

(b.) *Sessile-eyed Crustaceans*, or *Hedriophthalms*, have sessile eyes, and are divided into the following groups:—

1. *Amphipods*, . . . Crustaceans with feet in double row.
2. *Isopods*, . . . Crustaceans with simple and similar feet.

The *Amphipods* are sessile-eyed Crustaceans, having the first segment of the body distinct from the head, which carries a pair of foot jaws; tail formed of several segments furnished with bifid feet; body compressed and curved. These animals swim and leap with ease, always lying on their side; and they are generally marine.

The best known of the *Amphipods*, to ordinary observers, are the *Sand-hoppers* (Fig. 182), which are very common along our coasts, and collect in swarms under every bunch of seaweed left by the retiring tide; on disturbing the weed, the sand-hoppers emerge like a cloud, jumping into the air, by the repeated bending of the body. They are carnivorous, and feed principally on worms, which they attack with avidity, and soon kill and

devour. It is said that these little scavengers are capable of reducing a seal to the condition of a well-cleaned skeleton in less than two days. The *fresh-water shrimp* (*Gammarus pulex*) resembles the sand-hopper in the form of its body and in its mode of swimming; they live on animal food, but, in its absence, content themselves with nibbling at roots, fruits, and other



Fig. 182.

vegetable substances. These Crustaceans have been swallowed, and have lived for some time in the human body.

Certain of the lower Amphipods were long associated in a separate group, under the name of *Læmodipods*. These Crustaceans have sessile eyes, and the first joint of the body united to the head; the feet of this joint are placed far forward, under the head, which gives the animal the appearance of having feet on its throat, from which circumstance the family derives its name of *Throat-footed* Crustaceans. The *Læmodipods* do not swim, but creep on marine plants and animals in search of food. One of these singular animals is shown in Fig. 183, where it will be noticed that the second, third, and fourth pair of feet are furnished with two small



Fig. 183.

bladders at the base; these are gill vesicles, and the respiration of the animal is performed by means of them.

The *Isopods* have sessile eyes, and head distinct from the segment bearing the first pair of feet; the trunk is divided into seven segments, each furnished with a pair of undivided feet; tail formed of several rings, supplied beneath with leaf-like gill feet; antennæ four, the lateral ones always like bristles. The well-known *Wood-lice*, and *Sea-lice*, are the best types of the

Isopods; the greater number of them live in water, and those which live on land require very damp situations, such as under the stones along the sea shore, or under the loose mortar of old walls; they are capable of rolling themselves up into a ball, for protection when disturbed.



Fig. 184.

Many geologists believe that the fossil *Trilobites* were Isopods, and quote in illustration the *Serolis* of the coast of Senegal (Fig. 184). In this animal the usual seven pairs of feet exist, but they are so short as to be completely hidden under the edges of the dorsal rings. These Crustaceans are found at Terra del Fuego, as well as in Senegal, and the beach of many parts of the east coast of Patagonia is often covered with dead specimens. Captain King observed them swimming close to the bottom among the seaweed; they moved slowly and gradually, quite unlike shrimps, and were never seen to swim near the surface.

(c.) *Entomostracans*.—This term is here used in a restricted sense to include all the groups of Crustaceans characterised by the possession of a bivalve shell of horny texture, or of a thoracic carapace, so large that it looks like such a shell. They are divided into—

1. *Phyllopods*—Crustaceans with leaf-like feet.
2. *Cladocers*—Water Fleas.
3. *Ostracods*—Bivalved Crustaceans.
4. *Copepods*—Oar-footed Crustaceans.
5. *Epizoans*—Parasitic Crustaceans.

The *Phyllopods* have *eight pairs or more of leaf-like thoracic gill feet*, and sometimes *additional swimming feet* placed behind the gill feet; they have also two compound eyes. I have se-

lected as an example of the Phyllopods (Fig. 185), the little animal called by the Germans the *Fish-shaped-gill-foot* (fischförmige Kiefenfuss), called by us the *Fairy Shrimp*, and which is supposed to resemble the fossil Trilobites. It is found in stagnant water—even in pools at the road side, and is so like the larva of the *Mayfly*, that it puzzled at one time the sagacious Linnæus.

Linnæus first placed the Trilobites among the articulate animals under the name *Entomolitus paradoxus*; Latreille regarded them as having a close resemblance to the Mollusks known as *Chitons*; Wahlenberg revived the idea of Linnæus, and placed the Trilobites among the *Xiphurids*; while later writers have sought for affinities to Trilobites among the *Isopods* and *Phyllopods*; Van der Hoeven has strongly supported the view that regards them as gigantic Phyllopods.



Fig. 185.

The *Cladocera* are little Crustaceans furnished with a *bivalve horny shell*, having a dorsal fold, but no hinge; the head is free and projects from the shell, furnished with a beak; the *feet are leaf-like, thoracic, and five in number*, and are used as gills; the abdomen terminates in two bristles. In Fig. 186 *a* is shown the common Water flea (*Daphnia pulex*) which abounds in water tanks, and forms an excellent study with the microscope. In spring its colour is reddish, and, from its great numbers, it sometimes gives a tinge to the water of the entire tank.

The *Ostracods*, or *Potsherd* Crustaceans, are little animals furnished with a bivalve shell, hinged at the back; their feet are undivided, four or six in number, and useless for swimming, which is accomplished by means of two large jointed appendages, often regarded as posterior antennæ. One of the commonest of the fresh water forms, *Cypris*, is shown in Fig. 186 *c*. The *Cypris* lays her eggs, about eighty, upon the stems of vegetables,

or in the mud, and it has been found, as among the Aphides, that the female Cyprids produced from these eggs are fertile without the assistance of the male Cypris. Many fossil forms of these Entomostracans are known, and have been described by geologists. They extend back in time as far as the Devonian rocks, some members of which are called the *Cypridina slates*, in consequence of the immense numbers of little Cyprids preserved in them.

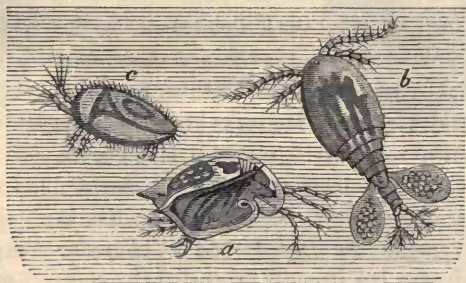


Fig. 186.

The *Copepods* or *oar-footed* Crustaceans, are characterised by an oval body, drawn out behind, and terminated by two bristles; the swimming feet are in four pairs, and cloven each into two oars. In Fig. 186 *b* is represented one of the best known of the Copepods, the *Freshwater Cyclops*. These voracious little animals abound in all stagnant pools, and do not hesitate, when hungry, to devour their own offspring.

The Epizoeic Crustaceans have a suctorial mouth, and the fore feet provided with hooks or suckers, for fixing the animal upon his prey; when young, these crustaceans swim freely about by means of feet furnished with long hairs, and resemble the young animals of *Cyclops* or Copepods; in their adult state they adhere parasitically to fishes, and are often deformed, and soft, with the body segments obliterated. These parasites vary greatly in appearance with the fish they infest; they are generally found inside the gill covers, where they meet with a constant current of

fresh water, and they are supposed to change their form with the fish which they select as their host.

(d). *Cirripedes*.—This remarkable and well-defined group of Crustaceans becomes fixed to a rock or other substance in adult life, and is then enclosed in a multivalve shell, which is frequently calcareous; no eyes; six pairs of feet, with short fleshy stalks, and two *cirri* with many joints, and horny; these cirri are used constantly by the animals, by extending them through the opening of the shell, for the purpose of introducing fresh water for respiration, and with it their daily food. Cirripedes are found in the seas of every part of the globe; they attach themselves to rocks and timbers used for building piers and harbours; but they especially delight in a moving home, such as a log of floating timber from a shipwreck, the hull of a vessel, or turtles and whales; it would seem as if their instinct taught them to attempt to counteract the disadvantages of their sessile life, by attaching themselves to objects endowed with a certain degree of independent locomotion. The best known of the Cirripedes are the *Sea acorns* (*Balanus*) and the *Barnacles* (*Lepas*).

The *Sea Acorns* or *Sea Tulips*, as they are called, have for their shells a sort of truncated cone, formed of pieces fitting upon each other with teeth; this shell is closed above by a lid formed of four pieces arranged in two pairs, and which are part of the covering of the crustacean itself; the four separate segments that form the lid can be closed by appropriate muscles, and the opening between them leads into the sack in which the body is lodged. The native species of *Balanus* are all small, and cover the rocks at low water with a white crust of shells, that cut the feet of swimmers; but the foreign species are well worthy of the title of *Sea Tulips*, from their large size and bright colours; they may easily be seen by examining the bottoms of ships just returned from the Mediterranean or from India.

The *Barnacles* or *Goose Mussels* (Fig. 187), illustrate well the structure of the Cirripede Crustaceans; their bodies are covered by four pieces of shell which correspond to the four parts of the lid of the *Sea Acorns*; while the single keel piece along the back of the *Barnacle* corresponds to the calcareous tube of the *Sea Acorn*, and its fleshy stem may be regarded as a prolongation of the same. The Barnacles derive their name of *Goose Mussel* from a fable invented by Scandinavian Monks, who asserted that a species of goose

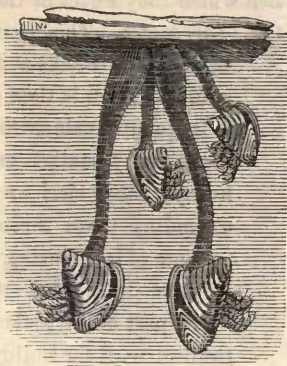


Fig. 187.

(*Anas bernicla*) had its origin from this Crustacean, and might be seen flying out from the Barnacle as a little gosling at certain seasons of the year; and since there could be no doubt as to the fishy origin of the *Lepas*, the goose was pronounced to be good fish also, and was freely used in Lent, as a supplement to the meagre diet proper for that season.

(e.) *Xiphurids*, or *King Crabs* (Fig. 188). These Crustaceans have six pairs of feet attached to the cephalo-thorax, the bases of which are spinous and surround the mouth, and serve it as masticators; six other pairs of feet are attached to the abdomen; these form semicircular plates, or swimming feet, to the last five of which the gills are attached. The body is composed of three parts; a cephalo-thorax or buckler, carrying two pairs of eyes, one pair kidney-shaped, and compound (Fig. 188 *a*); and the other pair simple (*b*); an abdominal or dorsal buckler having the form of an irregular indented hexagon; and a long sword-like tail articulated to the dorsal buckler, from which the animal derives its name. These Crustaceans are found in the Moluccas, and

on the coast of Nova Scotia in North America. They are called *Mimie* by the Malays, and *Umi-do-game* by the Chinese, and are much prized as food when full of eggs, which in July and August almost fill the cephalo-thoracic buckler of the females, and are discharged by two large oviducts which open on the back of the first abdominal segment. The King Crabs live in pairs, male and female, and are sold in pairs in the markets of Batavia. The Malays eat the eggs with avidity, and the flesh pleases them and the Chinese. I have eaten the eggs, which are inferior to the roe of



Fig. 188.

the lobster; but I regard the flesh as detestable, being almost as disagreeable as that of a young alligator. These Crabs live in a damp situation for more than a day out of the water, and when laid on their backs are unable to right themselves. Their tails form a powerful implement of defence, and are used by the Malays for spear-heads.

Some geologists maintain that the King Crabs, of all living Crustaceans, are the nearest congeners of the Trilobites.

E. Annelids, or Ringed Worms. The primary division of the articulate animals, as has been stated, page 295, is into Arthropods, or articulates with jointed feet, and Worms.

The Worms are divided into *Annelids* and *Scolecids*, in the first of which the true articulate structure of the body is more evident than in the second.

The body of Ringed Worms is generally much elongated and cylindrical; in some instances it is broader and oval in shape; it

is divided by transverse folds into rings or girdles, which are often very numerous. The common Leech has 100 rings, and *Phyllodoce*, one of the marine worms, has often upwards of 500 ring segments.

The organs for movement consist of bundles of hairs surrounding a central bristle, as shown in the section of a ring seg-

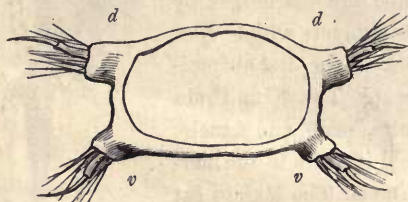


Fig. 189.

ment (Fig. 189). One pair of such bristle-shaped feet is placed on the dorsal arch of the ring (*dd*), and the other pair (*vv*) is placed in a corresponding position on the ventral arch. Locomotion is effected by means of these bristles pushing against the ground, like the ribs of snakes.

The nervous system consists, as in all the articulates, of a great ventral chain of double ganglions, through the collar formed by the first two of which the gullet passes: this anterior ganglion is called, for this reason, the *pre-æsoophageal* ganglion, and sometimes the *cerebral* ganglion.

No Annelid ever possesses a heart comparable in developement with the heart of a Crustacean or Insect; but a system of vessels is found, through which a clear fluid, red or green in colour, and seldom containing corpuscles, is driven by pulsations from behind forward—the dorsal vessel of this system acts as an arterial heart; in some Annelids, a venous ventral vessel is also found, through which the blood returns from before backwards. This circulation is called *pseudohæmal*, and it is considered by Huxley

not as a true circulation, but as a modification of the "water vessel" circulation found in the Scolecids and some of the Radiates.

Respiration is effected by the skin only, or by external gills of very different forms, or by vesicles or bladders on the sides of the body. The external gills are well seen in the common *Lug-worm* (Fig. 190), where they consist of eleven pairs of arborescent organs, placed externally, and rather in advance of the middle of

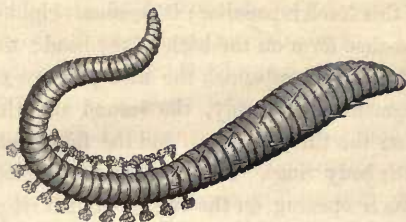


Fig. 190.

the body. Some of the ringed worms, like some insects, are capable of giving out a phosphorescent light, which appears to proceed from the bases of their bristle-like feet.

The Annelids are divided into three groups—

- a. Sucking Worms.
- b. Bristle-bearing Worms.
- c. Sipunculids.

(a.) *Sucking Worms* have the body ringed, without bristles, and terminated by a prehensile cavity at one or at both ends; no external gills. This division of Annelids includes the *Leeches* or *Bloodsuckers*; these animals can convert their heads into a sucking disk, and some are furnished with three saw-like teeth meeting at angles of 120° , with which they pierce the skins of their victims, previous to sucking their blood. Leeches have frequently an anal as well as an oral sucking disk, and they creep along the ground by affixing the suck-

ing apparatus, and by alternately contracting and expanding the body; they swim rapidly in fresh water, with a serpentine and sinuous motion of the entire body. The most useful of the Leeches is the well-known *Hirudo medicinalis*, which lives in fresh water, through the south and east of Europe; and in winter conceals itself in mud, rolled up in a circular form. It lives exclusively on the blood of other animals, both vertebrate and invertebrate. The arrangement of the eyes of this leech is peculiar; it possesses eight eyes arranged in horse-shoe form on the back of the head; these eyes consist of four pairs, of which the first pair are placed on the first segment of the body, the second and third pairs are placed on the third segment, and the fourth pair of eyes on the sixth body ring. The Leeches are Hermaphrodite, the *Spermducts* opening on the twenty-fourth ring of the body, and the *Oviducts* opening on the twenty-ninth ring; the leech, however, notwithstanding the possession of both testicles and ovaries, cannot fertilise its own ova; and it requires the assistance of a second leech to effect its impregnation. The common *Horse leech* of this country is distinguished from the medicinal leech by the absence of teeth. Some of the tropical leeches give poisonous bites; thus the bite of the *Hirudo Zeylanica* is followed by tedious and dangerous ulcers. Many fresh water and even salt water fishes are attacked by species of leeches peculiar to each; the Carp, the Tench, and the Ray have been especially noticed as thus favoured by Nature; fortunately for these fish, their leeches have no teeth, and are compelled to imbibe nourishment from their hosts, by simple suction.

- (b.) The *Bristle-bearing* or *Setigerous* Worms are divided into two groups; in the first of which respiration is effected by means of internal sacks opening by pores along the ventral side of the abdominal rings; and in the second, respiration takes place by means of external arborescent gills.

The common *Earth-worm* may be taken as a representative of the first group. Respiration is effected in this animal by means of more than 100 vesicles opening on the abdominal surface; in addition to their use as respiratory organs, these vesicles also secrete a glairy mucus, that serves to lubricate the external surface. The Earth worm has its bristles, which are not retractile, arranged in longitudinal rows; the bristles are short and stiff, eight in every ring, and on each side two pairs, so that eight rows of bristles run longitudinally down the body; and there is also a dorsal row of hairs down the centre of the back.

The intestinal canal of the Earth worm (*Lumbricus*) is straight and wide; it contains a crop (*proventricle*) and gizzard (*muscular stomach*); behind the gizzard, the intestine is divided by many transverse folds into cæca, or blind pouches, the secretion from which is supposed to correspond to that of bile. The intestinal tube becomes slightly narrower, after receiving the secretions from the cæca, and afterwards widens to its former dimensions.

The second group of Setigerous Worms contains two divisions; the first of worms living in fixed tubes, and having gills placed near the head, called *Tubicolous* or *Cephalo-branchiate* Worms; and the second containing the naked roving Worms; with gills placed in rows upon their backs—these Worms are hence called Roving or *Notobranchiate** Worms.

The *Tubicolous* Worms often form their tubes of grains of sand cemented by a glutinous substance; others again form their tubes of pieces of broken shells; and others, as *Serpula* and *Spirorbis*, possess the power of secreting calcareous shells, in which they permanently reside—these worms were until lately confounded with Mollusks for this reason. The *Serpula* (Fig. 191) has two large comb-shaped gills arranged like fans, with a cylindrical set of filaments

* In the barbarous Græco-Latin tongue used by Naturalists, this is generally called *dorsi-branchiate*.

carrying an operculum, or lid, which closes the shell when the worm retracts its head. The shell itself is calcareous, twisted into an irregular convoluted spire, and is generally attached to the shells of some species of mollusk, as the oyster, sedentary in its habits.

The *Notobranchiate* Worms may be illustrated by the *Lugworm* already figured (Fig. 190), and by the active little marine worm known to fishermen as *hairy bait* (Fig. 192).

The *Lugworm* (*Arenicola piscatorum*), Fig. 190, has rudiments of feet, with a dorsal fasciculus of bristles, and a ventral row very minute, and incurved; the gills are arborescent and placed in rows in the middle of the body; the body is thickened forwards, in front of the gills, and becomes smaller behind the gills, where it has no rudiments of feet or of bristles. This worm lives in deep canals excavated in the sea sand, which the worm forms with its head, while the sand is swallowed and passed through the intestinal canal; it is flesh-coloured or blackish, while its gills have a brighter colour, and it exudes a yellow fluid on being handled.



Fig. 191.

The little worm called *hairy bait* (*Nephtys*, Fig. 192) has



Fig. 192.

its head truncated, and furnished with four small tentacles; its rows of dorsal and ventral bristles or feet are separated by a row of strap-shaped gills.

The beautiful animals called *Sea mice* belong to the group of

Notobranchiate Worms; they are furnished with a row of horny scales, or plates, instead of tufts of bristles covering the dorsal feet; the head is concealed and protected by the anterior scales, which project beyond it. It is generally five or six inches long, and one and a-half inch broad; the bristles on the sides of the body are glistening, green and red, and showing the varying colours of the rainbow; the back is covered with a dense felty covering of interwoven hairs; when this covering is opened, fifteen nearly circular plates are seen on each side, which partly cover each other, the central being the largest. If two consecutive plates be separated, there are seen on the body segment, or ring that lies between them, small longitudinal nodes separated by a pit, and furnished on the outer and back side with comb-shaped gills that look as if they had been torn at the margins.

(c.) *Sipunculids*.—The *Siphon worm* (*Sipunculus*, Fig. 193), and



Fig. 193.

its allies, classed by former naturalists with the Radiates, are now placed among the Annelids, of which class they constitute a distinct order (*Gephyrea*).

F. *Scolecids*.—The *Scolecids* form the last and the lowest division of Articulate animals; and are divided into the following groups:—*

- a. *Rotifers*—Wheel animalcules.
- b. *Turbellarians*.
- c. *Trematodes*—Flukes.
- d. *Cestodes*—Tapeworms.
- e. *Nematodes*—Threadworms.
- f. *Acanthocephalids*.
- g. *Gordians*.

* Vide Huxley's Elements of Comparative Anatomy.

Of these subdivisions of Scolecid worms, the last five are parasitic, and exhibit anomalies of structure and of developement, such as might be expected from creatures living under such exceptional conditions.

Most of these animals agree in the possession of what is called the *water vascular system*, formed of a remarkable set of vessels, communicating with the exterior medium by means of one or more apertures situated on the surface of the body, and branching out, more or less extensively through the interior of the substance of the body of the animal itself. In none of these Scolecids has any true circulatory apparatus been discovered. The water vascular system may be said to perform the offices of circulation and respiration by means of the same system of organs.

The nervous system in the Scolecids consists of only one or two closely approximated ganglions.

(a.) *Rotifers*, or *Wheel Animalcules*, are microscopic Scolecids, contractile, crowned with vibratile cilia at the anterior part of the body, which resemble a wheel revolving rapidly; intestine distinct, having a mouth and an anus; sexes distinct, oviparous in

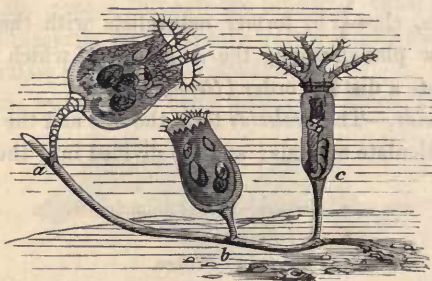


Fig. 194.

winter, viviparous in summer. The general appearance of these animalcules under the microscope may be understood from Fig. 194, which represents the Rotifer called *Bra-*

chionus (*a*, *b*), characterised by having two rotating disks, and finger-shaped jaws, and the Rotifer called *Stephanoceros* (*c*). The rotation of the disk is an optical illusion caused by the successive motion of the cilia on the margin of the disk; the motion of the cilia is subject to the control of the animal itself.

The *Rotifers* are capable of contracting their bodies, so as to assume an oval shape, and many of them are furnished with a tail-like appendage, which can be drawn in and out, like a telescope, and by means of which the animalcule attaches itself to the place selected for its fixed abode. The motion of the vibratile cilia serves for a double purpose: when the animal is fixed, they form a perpetual current of water setting in towards the mouth, which is furnished with lateral jaws like those of crustaceans or insects, so that the smaller animalcules, called *Infusories*, are carried by this current into the mouth of the Rotifer, and there destroyed; on the other hand, when the animal is not fixed, the vibrating, rotatory, movement of its cilia acts like a ship screw of the most delicate and perfect description (because it is flexible, and so takes the form of the *screw of least slip*), and propels the little creature from place to place until it suits his purpose to rest and seek his food.

The sexes are distinct in Rotifers, the female being the most important; she is furnished with an œsophagus, a stomach, pancreatic glands, and cæcal cells that serve the office of a liver; in fact all the digestive machinery requisite for the enjoyment and assimilation of a great variety of food; her male partner, on the contrary, has neither mouth, nor intestine, nor anus; he never eats, because his life is destined to be so short, that it is not worth while to provide him with a stomach or mouth; his sole business in life is to secrete sperm for a short time, and as soon as he has fertilized the female, he must die. The *Rotifers*, however, cannot be accused of the cruelty of the old maid Bee workers, who kill the drones when they have done their duty;

nor of the barbarity of the matron Spider, who eats her husband after she has embraced him, coolly performing the part assigned by Danaus to his daughter Hypermnestra :—

“ I nil,” quod he, “ have none excepcioun.”
 And out he kaughte a knyf as rasour kene.
 “ Hyde this,” quod he, “ that hyt be not ysene ;
 And whaune thyn housbonde ys to bedde goo,
 While that he sleepeth kut hys throte atwoo.”*

There is something most hateful to our higher feelings in the instinct of the spider that eats her mate, or in that of the lioness that devours her cubs, when unable to suckle them ; in order that no particle of assimilable food shall be allowed to go to waste. The economy of material, and of food, shown in such strange instincts, teaches us that nature has her dark as well as her bright side, and that she presents, in her lower forms, instincts and passions, which, if imitated by man, would justify cruelties towards the poorer members of society, such as have not (as yet at least) entered into the hearts of political economists to conceive.

An Egyptian fable informs us that the votaries of the goddess Nature were divided in opinion, as to whether she was transcendantly beautiful or hideously ugly ; and that, in order to keep up the mystery on this subject, she always wore a thick veil over her face ;

For with a veil that wimpled everywhere,
 Her head and face was hid that mote to none appear.
 That, some do say, was so by skill devised,
 To hide the terror of her uncouth hue
 From mortal eyes that should be sore agrised,
 For that her face did like a Lion show,

* Legende of goode women.—*Chaucer.*

That eye of wight could not endure to view :
 But others tell that it so beauteous was,
 And round about such beams of splendour threw,
 That it the sun a thousand times did pass,
 Nor could be seen, but like an image in a glass.*

- (b.) *The Turbellarians*.—These animals, like the Rotifers, are not parasitical, but they deserve to be so, from their degraded structure. They possess a cylindrical, or depressed body, generally without segments, but having transverse wrinkles, and covered with vibratile cilia. They are divided into two families, of which the *Planaria* and the *Nemertes* are characteristic types. They are called *Turbellarians* from the currents and rotatory movement developed in the surrounding water, by their cilia.

The *Planaria* (Fig. 195) has a digestive canal with one aperture only, and without an anus; body without ring segments. They possess a mouth situated near the centre of the body, on



Fig. 195.



Fig. 196.

the ventral surface; and the intestinal canal branches off in various directions through the jelly-like mass of the body, terminating always in blind pouches.

The *Nemertes* (Fig. 196), or *Long sea worm*, often reaches the extraordinary length of ninety feet, and is found on the sea

* Faerie Queen—Mutabilitie.

shore, coiled up in gordian knots, under the loose stones. It has a simple intestine, with an anterior mouth, and terminal anus, and is roundish, or slightly depressed, with imperfect marks of body rings—the head is distinct, and it possesses from four to fourteen eyes, arranged in pairs.

- (c.) The *Trematodes* or *Flukes*, are internal worms, infesting the body of man, sheep, and especially fishes. They have a general resemblance to the Planarians. The body is depressed or roundish and soft; they are furnished with suckorial disks, and have a branching intestinal canal; one of the suckorial disks leads into the mouth, and the others are blind. They are found abundantly in the sheep's liver, and in the gall-bladder of Man, the Ox, Deer, and others; some of them, also, live gregariously in the eyes of certain fishes; others are found in pairs, lying in elastic tumours under the skin of the belly and thighs of Finches; while those that live on the skin, or in the gills of fishes, are almost countless.
- (d.) The *Cestodes*, or *Tape Worms*, are better known than liked; they possess an elongate, flat, jointed body, well described by the term Tape worm; they have no mouth, but the head is furnished with suckorial pores. Three kinds of this dreaded pest infest the small intestines of man; the Russian Tape Worm (*Bothriocephalus latus*), the common Tape Worm (*Tænia solium*), and a third species, scarcely less abundant (*Tænia mediocanellata*). The Russian Tape Worm is found abundantly in Lapland and Russia, in Man, and in the Polar Bear; it is broader than the common Tape Worm, and attains a length of twenty feet. The common Tape Worm (*Tænia solium*), or Internal Worm that sits enthroned in state, called by the French *ver solitaire*, owes both his Latin and his French name to the mistake, that in the same person one such worm only can be found. It infests the people of Western Europe, and is occasionally to be met with in the same intestine, in company with its rival, the *Bothriocephalus latus*.

It has been satisfactorily proved, that the internal worms, called *Cystic Worms*, from being enclosed in a bladder-like vesicle, are really the undeveloped forms of the dreaded Tape worms, waiting for admission into a suitable host, such as Man or the Polar Bear, for their further developement. These undeveloped worms are called *Hydatids*, and are met with in many domestic animals, in the liver, the abdominal cavity, and even in the heart and brain. The Cystic worms of the pig are believed to be the undeveloped Tape worm of Man; and a Cystic worm found in Rats has been proved to be the same as the developed Tape worm peculiar to Cats; thus the animals we devour avenge their deaths by filling our intestines with living mementoes of parasites that once troubled themselves, and thus their very enemies avenge their slaughter.

(e.) *The Nematodes*, or *Thread Worms*, contain several species interesting to man from their attacks upon him. They possess a mouth, and anus terminating an intestine suspended in a distinct abdominal cavity; sexes distinct; body round, elastic, sometimes thread-shaped.

The *Ascaris lumbricoides*, or *Round worm*, infests the intestinal canal of man, and attains the length of fifteen inches. It is named *lumbricoides* from its external resemblance to the Earth worm. It is considered to be different from similar worms that infest the intestines of the Horse and Pig. In children, it is sometimes vomited, having made its way upwards into the stomach; and it has been known to creep out of the nose of a sleeping child; and has been even accused of causing death, by mistaking the windpipe for the gullet, in its explorations, and so causing suffocation.

The *Oxyuris vermicularis* lives in bundles in the large intestine, especially of children, and never wanders far from the anus; it often causes serious nervous symptoms, even epilepsy; but its low tastes cause its destruction, for as it never leaves the large

intestines, the skilful disciple of Esculapius attacks the colony with a turpentine glyster, and speedily routs it in dismay.

The *Guinea worm* (*Filiaria Medinensis*) lives in the cellular tissue, under the skin of man, especially in the legs, and attains a length of ten feet; it is endemic in Curaçoa and in some hot countries of the Old World, and often causes severe pain. It is viviparous, and it is remarkable that the male worm has never yet been found; all the specimens examined by naturalists, hitherto, having proved to be females.

(f.) *Acanthocephalids*, or *Spiny-snouted Entozoans*.—These worms have a *roundish bladder-shaped body, marked with transverse wrinkles; no mouth or intestine; proboscis retractile, and armed with recurved hooks; sexes distinct*. They are found in the intestinal canal of many birds and fishes; also in that of the Pig and the Seal. Upwards of 100 species of *Echinorhyncus* have been described, one of which (*E. porrigens*) is common to the Eider Duck, and lesser Rorqual Whale; it is found in the duodenum of that whale, where its presence is indicated by large fleshy papillæ in the mucous membrane of the intestine; the openings of these papillæ from the intestine lead into tubular cavities, situated obliquely between the mucous and the muscular coats of the gut, in each of which lies ensconced a formidable looking *Echinorhynchus*. Specimens of this dreadful entozoon have been recently found in the intestines of the short-tailed monkeys, and, let us hope, may yet be found in man.

(g.) The *Gordians*, or *Hair Worms*, are *hair-like, extremely slender and elastic; anus none; sexes distinct*.—These worms are found commonly in summer time in ponds and ditches, and so closely resemble horse's hairs that they are believed by schoolboys and country folk to be living hairs. They are scarcely separable from the lower Nematodes. In the imma-

ture stages of their existence, they are parasites in the interior of certain insects, especially *Water Beetles*, where they grow to a length of ten or eleven inches, and then escape from the body of their victim, to seek some sheltered pool in which they may lay their eggs, which may be found fastened together in long chains.

3. **Mollusks.**—The Mollusks form the second grand subdivision of invertebrate animals; they possess a body covered by a skin, soft and constantly moist, to which muscles are attached, and in which, or by which, a calcareous secretion, forming a shell, is usually produced. This external skin or mantle encloses both the intestines and the nervous ganglions.

The *Nervous System* in Mollusks consists of distinct ganglions, connected by nervous filaments, and never so symmetrically arranged in pairs, as among the articulate animals. The difference between the nervous systems of the articulates and mollusks may be seen from a comparison of Figs. 109 and 110.

Many naturalists divide the Mollusks into two groups, according to the arrangement of their nerve ganglions; in the first division, which embraces the most highly organised of these animals, there are always three principal pairs of nerve masses, united into ganglions, and called, respectively, the *cerebral*, the *parietosplanchnic*, and the *pedal* ganglions: these ganglions preside respectively over the *senses*, the *digestion* and *reproduction*, and the *locomotion* of the Mollusk; in the second division of mollusks, sometimes called Molluscoids, the nervous system is greatly simplified, being reduced to a single principal ganglionic mass, which usually detaches a nervous collar round the œsophagus, and affords origin to other nerve filaments distributed throughout the body. As a consequence of this imperfect developement of the nervous system, the functions of the animal life are less developed than in the articulates, and the movements of Mollusks are, on the whole, creeping and slow, and those of them that possess a

springing motion, as certain Bivalves and the Cephalopods, exert their muscular power in a more uncertain and irregular manner than the higher articulates.

The Vegetative or visceral life of the Mollusks is much more perfect than their animal life ; most of them possess an arterial heart, which receives the blood from the gills or lungs, and distributes it by arterial tubes to the different parts of the body (Fig. 179). Capillary blood vessels are wanting, and the veins are replaced by *sinuses* or cavities in different parts of the body, in which the blood collects before returning to be oxidised in the gills. The arterial heart of the first or highest division of the Mollusks shows its superiority to the second division, as clearly as did the nerve ganglions. In the higher Mollusks, there is a distinct auricle and a distinct ventricle in the heart ; while in the lower forms (Molluscoids), the heart is saccular, and not divisible into an auricle and a ventricle.

4. Classification of Mollusks.—The Mollusks are divided into the following classes :—

A. Cephalopods.	}	Mollusks proper.
B. Pteropods.		
C. Gasteropods.		
D. Lamellibranchs.		
E. Brachiopods.	}	Molluscoids.
F. Tunicates.		
G. Polyzoans.		

A. Cephalopods.—The Cephalopods are Mollusks with a *distinct head, having the organs of motion (tentacles) surrounding the mouth in a ring ; gill cavity, open in front ; sexes distinct ; respiration by gills ; marine*. Locomotion is effected among the Cephalopods, partly by means of their arms or tentacles, but chiefly by means of the propulsion of water from the gill sack, through a funnel placed under the head ; the mantle or skin surrounds the body loosely, forming a large gill sack, opening to the external water by means of an aperture under the head (in the

middle of which the funnel is placed, furnished with muscular walls; by the sudden contraction of the mantle, the water contained in the gill sack is forced out through the funnel, and the Cephalopod is suddenly jerked in the opposite direction by its reaction. The intestinal canal and the genital organs discharge their contents into the large gill sack formed by the mantle. The Cephalopods are more symmetrical than most other Mollusks, their right and left sides being equally developed; they have powerful jaws, furnished with horny curved points, like a parrot's bill, and a large fleshy tongue; their eyes and optic nerves are very large, and their eyes are placed on the side of the head; their senses are acute; and they are predatory in their habits, living upon shell fish, crabs, and fishes.

The Cephalopods are divided into two groups, according to the number of their gills, which is either two or four; these gills are conical, and run obliquely upwards, situated one at each side, in the base of the gill sack. These two divisions are called—

a. Dibranchiate Cephalopods.

b. Tetrabranchiate Cephalopods.

In the *Dibranchiate* Cephalopods, a branchial heart is situated at the base of each gill, to propel the blood into that organ; these two hearts are in addition to the usual arterial heart, and are wanting in the *Tetrabranchiate* Cephalopods. In both divisions, there are found, surrounding the large venous stems that convey the blood to the gills, spongy appendages, of a yellowish brown colour, with blind follicles, which are regarded by anatomists as fulfilling the office of kidneys.

(a.) *Dibranchiate* Cephalopods. *Swimming, naked, Mollusks; head distinct; eyes sessile, prominent; mandibles horny; arms eight or ten, furnished with suckers; body round or oval, usually with a pair of fins; gills two, furnished with venous hearts; ink gland always present; wall of the funnel entire; test internal (Argonautá exceptá), horny or shelly, with or without chambers.*

The Dibranchiate Cephalopods are also called *Acetabuliferous*, from having suckers upon their tentacles; they are subdivided into (α) *Octapods*, and (β) *Decapods*, according to the number of their arms.

- (α .) The *Octapods* contain the two families of *Argonauts*, and *Polypes*, the first of which is characterised by its females possessing external shells. The *ink bag* is a tough and fibrous organ, opening into the gill sack cavity near the point of discharge of the intestine; and its secretion is used by the Cuttle fish to darken the water, and so cover its retreat, in flying from a pursuer.

The *Argonaut* (Fig. 197) is an *Octapod*, whose female is

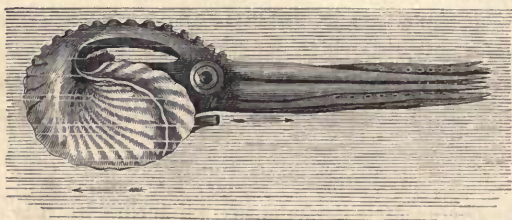


Fig. 197.

furnished with a single chambered shell, secreted by the two dorsal arms; the figure represents the Argonaut, swimming by the expulsion of water through the funnel of the gill sack; the transparent shell of this beautiful animal is not fitted to the body, nor attached to it by shell muscles; it is essentially an external appendage secreted by the arms; the animal swims like other Cuttle fish, by discharging water through its funnel, and when feeding, walks upon the sea bottom, with its head and arms down, and shell inverted. The Argonaut has four species still living, and one of these, which is found in the Chinese seas, is also found fossil in the Sub-Appennine and Tertiary beds of Piedmont.

Aristotle was well acquainted with the Mediterranean species, which he thus describes:—

“The Argonaut is a polype singular in its nature and in its actions, for it sails upon the surface of the sea, having first ascended from the deep water; it ascends with an inverted shell, in order that it may go out more readily and sail in the empty shell; when it reaches the surface it turns the shell over. It has between its tentacles a web like that of web-footed birds, except that theirs is coarse, and this is thin, and like that made by a spider; this it uses for a sail when the wind blows, and it employs two of its tentacles instead of a rudder. If it be frightened, it goes down, having first filled the shell with sea water.”

The *Polype* resembles the other Cuttle fish, in having no shell, but it differs from them in the number of its tentacles, which are eight instead of ten, and are symmetrically arranged round the head. It is a most unamiable and voracious brute (Fig. 198), devouring shell fish, and even the formidable Cray fish. Aristotle made many accurate observations on the *Polype*, which show that he well knew the difference between this Octapod and all the other Cuttle fish. He mentions that they are the only Cuttle fish that

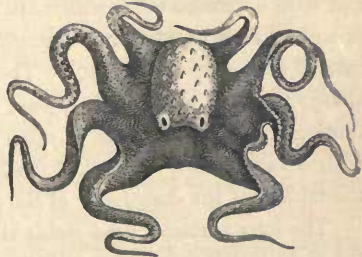


Fig. 198.

come ashore, that they live in holes in the rock, which are found by the fishermen observing the shells broken by the *Polype* for food; and also states that the Cray fish, if caught in the same net with a *Polype*, will actually die of terror. Homer compares Ulysses holding on to the rock so tenaciously, as to leave the skin of his fingers behind, to the polype torn from its hole, and carrying pieces of small stones attached to its suckers.

ὥς δ' ὅτε πολύποδος, θαλάμης ἐξελκομένοιο,
 πρὸς κοτυληδονόφιν πυκιναὶ λάγγες ἔχονται,
 ὥς τοῦ πρὸς πέτρῃσι θρασειάων ἀπὸ χειρῶν
 ῥινοὶ ἀπιδρυθεν, τὸν δὲ μέγα κῦμα κάλυψεν. Od. ε.

As when the Polype fish enforced forsakes
 His rough abode, with his adhesive cups
 He gripes the pebbles still ;
 So he, Ulysses, with his lacerated grasp,
 The crumbled stone retained, when from his hold
 The huge wave forced him, and he sank again.

COWPER.

These formidable animals have been found in the open sea, off Teneriffe, fifteen to eighteen feet long, with arms estimated at six feet in length. A gigantic beast of this description has been made the hero of one of Victor Hugo's novels.

(β.) The *Decapod* Dibranchiates contain the *Squids*, the *Belemnites*, the *Cuttle fishes* proper, and the *Spirules*.

They have *two of the tentacles much longer than the other eight*, and with expanded ends, which are sometimes furnished with hooklets for seizing their prey, instead of suckers (Fig. 199). Their body is always provided with a *pair of fins*; the funnel leading from the gill sack is often furnished with a valve; *shell internal*, lodged loosely in the middle of the dorsal side of the mantle.

The long tentacles arise inside the circle of the eight regular arms, between the third and fourth pairs, and are sometimes six times the length of the animal; they are more or less retractile into large subocular pouches; and serve to seize prey beyond the reach of the ordinary arms, or to moor the fish during a gale. The shell of the Decapods lies loosely within the mantle and falls out when the sack containing it is



Fig. 199.

opened. The four families of Decapods are distinguished by the different structure of their internal shell.

1. The *Squids* have a horny shell consisting of three parts; viz., a shaft, and two lateral expansions or wings; this arrangement gives it a resemblance to a pen, from which circumstance the Squids are also called Calamaries (of, or belonging to, a writing reed).
2. The *Belemnites* have a pen-shaped shell terminating posteriorly in a chambered cone (called *phragmacone*), containing a siphuncle running close to the ventral surface.
3. The *Cuttle fishes* proper (*Sepia*) have a calcareous shell, consisting of a broad laminated plate, terminating behind in a hollow imperfectly chambered apex.
4. The *Spirules* have a pearly shell, discoidal, with separate whorls, chambered, with a ventral siphuncle.

The Squids are used for bait in great numbers, and it is computed that half the cod fish captured on the Newfoundland banks are taken with Squids; when the fishing season approaches, frequently 400 to 500 sail of English and French ships are engaged in the Squid fishery. After a severe gale, hundreds of tons of these Decapods are thrown ashore on the flat beaches, the decay of which spreads an odious stench around. They are very prolific, and their egg clusters are computed to contain 40,000 eggs each.

The Belemnites have been found fossil, to the number of 100 species, all belonging to the secondary deposits; and they owe their preservation to the infiltration of calspar into the phragmacone, which corresponds to the terminal appendix of the Calamaries. The phragmacone, which is really an internal chambered, siphuncled, shell, is covered externally by a guard which is commonly called the *belemnite*; this guard is very variable in its proportions, varying from half an inch beyond the phragmacone to two feet.

- (b.) *Tetrabranchiate Cephalopods.* *Animal creeping, protected by an external chambered and siphuncled shell ; eyes pedunculated, beak calcareous ; tentacles very numerous, without suckers ; four gills ; body attached to shell by adductor muscles ; funnel incomplete.*

These remarkable Mollusks are known to us in the living state by a single animal, the *Nautilus pompilius*, and upwards of 1400 different kinds are known by their fossil shells ; they may, therefore, be regarded as nearly extinct. The following Families are contained in the Tetrabranchiates, all of which, except the first, are fossil only :—the *Nautilids*, the *Orthoceratites*, and the *Ammonites* ; of these, the Nautilids are found in every formation and period of the Earth's history, including the present ; the Orthoceratites are found in the Palæozoic period only ; the Ammonites in the Palæozoic and Mesozoic periods. We know little of the habits of the Nautilus, except that it is a creeping and not a swimming cephalopod, and spends its life among coral reefs, at twenty to thirty fathoms deep, seeking for food in the shells with which the coral rocks abound. The following account of the Dutch naturalist Rumphias (1705) reminds us of the description of the sailing of the Argonaut already quoted from Aristotle.

“ When the *Nautilus* floats on the water, he puts out his head and all his tentacles, and spreads them upon the water, with the poop of the shell above water ; but at the bottom he creeps in the reverse position, with his boat above him, and with his head and tentacles upon the ground, making a tolerably quick progress. He keeps himself chiefly upon the ground, creeping also sometimes into the nets of the fishermen ; but after a storm, as the weather becomes calm, they are seen in troops, floating on the water, being driven up by the agitation of the waves. This sailing, however, is not of long continuance ; for having taken in all their tentacles, they upset their boat, and so return to the bottom.”

B. *Pteropods.*—*Mollusks furnished in front, on both sides, with a swimming fin ; head not well separated from body ; hermaphrodite ;*

marine. These little animals are generally enclosed in a sub-conical shell, and have a resemblance, easily recognised, to each other. Their whole life is passed in deep water, far removed from any shelter save what may be afforded by floating seaweeds. They swim by the vigorous flapping of their little pair of fins (Fig. 200), and are ornamented, rather than protected, by their glassy shell. They form, in high latitudes, the food of whales and sea birds, and their shells are rarely drifted ashore, but are found in countless myriads in deep sea dredgings. Their nervous structure is highly developed, consisting, like that of the Cephalopods and Gasteropods of three principal pairs of ganglions. Huxley considers the aberrant shell *Dentalium*, to belong to the Pteropods, and not to the Gasteropods.



Fig. 200.

C. *Gasteropods*.—*Mollusks with head distinct from body, with tentacles; the inferior surface of body flattened into a disk that serves as a foot for locomotion.* These are commonly known as slugs, and univalves; their heart is generally on the left side of the body, and the spire of the shell right-handed; but in some the heart is placed on the right side of the body, and the spire of the shell becomes left-handed. The flattened disk, which is muscular, and well known in snails and slugs, gives the name to the entire class; but in one order (*Heteropods*) it is converted into a swimming organ. The Gasteropods are divided by Milne Edwards into the following Orders:—

- a. *Prosobranchiate*—Gills in front.
- b. *Pulmobranchiate*—Lungs for gills.
- c. *Opisthobranchiate*—Gills in rear.
- d. *Heteropods*—Feet abnormal.

(a.) The *Prosobranchiate* Gasteropods have the abdomen well developed and protected by a shell, into which the whole

animal can retire; the mantle forms a vaulted chamber over the back of the head, in which the excretory orifices and gills are usually placed; the gills are comb-shaped and placed in front of the heart; sexes distinct. The Prosobranchiate Gasteropods are divided into two groups, called *Siphonostomate* and *Holostomate*, according as the aperture of the shell is notched or entire; the notched shells are inhabited by carnivorous Mollusks, and the shells having the margin of the aperture entire, are generally herbivorous, and are called Sea Snails.

The characters of these two sections, and the natural families included under each, are as follows:—

Siphonostomates; shell spiral, usually imperforate; aperture notched or produced into a canal in front; operculum horny, lamellar; carnivorous; all marine; furnished with a siphon formed by the margin of the mantle, by means of which water is admitted into the gill chamber.

Family 1. Strombidæ—Wing shells.

„ 2. Muricidæ.

„ 3. Buccinidæ—Whelks.

„ 4. Conidæ—Cones.

„ 5. Volutidæ—Volutes.

„ 6. Cypræadæ—Cowries.

The *Snipe-billed Murex* of the Moluccas (Fig. 201) gives a good idea of the peculiarity from which the whole section of Siphonostomes is named; the frontal notch is here prolonged into an almost tubular expansion for the protection of an equally long retractile proboscis, and of the siphon which admits water to the gill chamber.

The external appearance of the Carnivorous Gasteropods is well shown in Fig. 202, which represents the animal of the

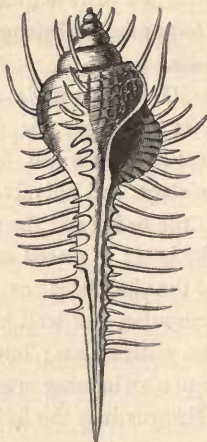


Fig. 201.

Tunshell (*Dolium*), one of the Buccinidæ, with exserted *proboscis* (*p*), and respiratory *siphon* (*s*) turned back over the shell.

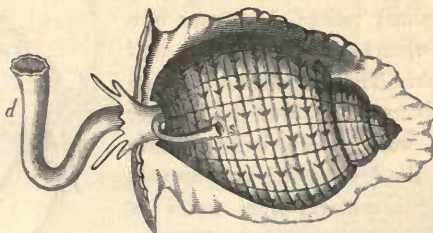


Fig. 202.

Holostomates; shell spiral or limpet-shaped; margin of aperture entire; operculum horny or shelly, usually spiral; animal with a short muzzle, respiratory siphon absent, or formed by a lobe developed from the neck; marine or freshwater; mostly herbivorous.

- Family 1. Naticidæ—Sea Snails.
 „ 2. Pyramidellidæ.
 „ 3. Cerithiadæ—Cerites.
 „ 4. Melaniadæ.
 „ 5. Turritellidæ.
 „ 6. Litorinidæ—Periwinkles.
 „ 7. Paludinidæ—River Snails.
 „ 8. Neritidæ—Nerites.
 „ 9. Turbinidæ—Top shells.
 „ 10. Haliotidæ—Ear shells.
 „ 11. Fissurellidæ—Key-hole Limpets.
 „ 12. Calyptræadæ—Bonnet Limpets.
 „ 13. Patellidæ—Limpets.
 „ 14. Chitonidæ—Chitons.

We may select the apple shell (*Ampullaria*) of the West Indies (Fig. 203) as a typical example of the *Holostomes*; this

animal possesses two pairs of feelers, a pair of stalked cephalic eyes, and a long recurved cervical respiratory siphon (*s*); and its shell is closed, when the animal retires, by means of a shelly operculum (*o*) placed on the back of the foot disk. The *Ampullaria* inhabits lakes and rivers throughout the warmer parts of the world, and retires deep into the mud in the dry season; it is capable of surviving a removal from water of many years' duration. It is well known as a fossil shell, but although freshwater, and different in habits and structure of animal from *Natica*, it is often difficult to decide whether a fossil water snail of this form indicates the former presence of salt water or fresh.



Fig. 203.

(*b.*) The *Pulmobranchiate* Gasteropods, as their name implies, breathe by lungs and not by gills; they are typical Gasteropods, having a broad muscular foot and sometimes a large spiral shell; their air chamber is the simplest form of lung imaginable, and is like the gill chamber of the Branchiate Gasteropods, but lined with a net-work of respiratory vessels, on which the air acts instead of water. The land snails are arranged in two divisions, according as they have an operculum or not; but many of the Pulmogasteropods have no shell at all. They are usually arranged in the following Families:—

Family 1. Helicidæ—Land Snails.

„ 2. Limacidæ—Slugs.

„ 3. Oncidiadæ.

„ 4. Limnæadæ—Pond Snails and River Limpets.

„ 5. Auriculidæ.

„ 6. Cyclostomidæ } Operculate Snails.

„ 7. Aciculidæ }

The land snails are so well known that it is unnecessary to describe them; in Fig. 204, *a*, is shown a typical Slug (*Limax*), having a small shield-shaped mantle, containing a rudimentary

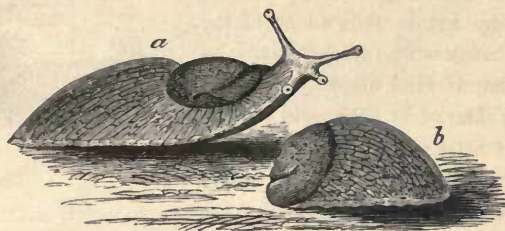


Fig. 204.

nail-shaped shell concealed by the mantle; in Fig. 204, *b*, is shown the manner in which the Slug, when alarmed, withdraws his head from observation beneath the shelter of the mantle.

- (*c.*) The *Opisthobranchiate* Gasteropods have no shell or a very rudimentary one; gills arborescent, not enclosed in a gill chamber, but exposed on the back and sides, towards the hinder part of the body, behind the heart; hermaphrodite. These animals are called popularly *Sea slugs*, and have the power, when alarmed, of retracting their gills and tentacles, so as to present the appearance of a shapeless mass.

The nervous system of pairs of ganglions corresponding to the cerebrospinal system of the higher animals, is well developed in the Sea Slugs. They possess a pair of *olfactory* ganglions at the base of the tentacles, and a pair of *optic* ganglions at the posterior border of the *cerebral* or *cephalic* ganglion, which lies in front of the gullet; the auditory capsules, formed of little vesicles filled with fluid, and containing *earstones* (*otoliths*) in constant vibration, are attached to the cephalic ganglion itself, just behind the optic ganglions; these all lie in front of the gullet, which passes through the ring or collar formed by nerve filaments connecting the cephalic ganglion with the pairs of *buccal*

and *pedal* ganglions, called *subœsophageal*; behind these come the *branchial* pair of ganglions, and lastly the great single ganglion called *visceral*. I have selected two of the Sea Slugs to illustrate the entire group.

In Fig. 205 is shown one of the *Sea lemons* (*Doris*), characterized by plume-shaped gills placed in a circle in the middle of its back, and by two blunt tentacles placed rather far back, behind which the sessile eye specks may be seen in young specimens.



Fig. 205.

In Fig. 206 is shown an *Eolis* characterised by rows of bud-shaped out-growths arranged down the back, and by long and non-retractile tentacles.

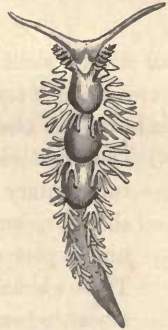


Fig. 206.

(d.) The *Heteropods*, also called *Pterobranchiate* and *Nucleobranchiate* Gasteropods, consist entirely of oceanic forms, which swim at the surface instead of creeping at the bottom of the sea; their foot is compressed into a fin, and furnished with a sucking disk, by means of which they attach themselves to floating seaweeds; their gills are comb-shaped and placed on the back, being often protected by a delicate glassy keeled shell; they frequently attain a considerable size, and feed upon small *Sea nettles* and *Pteropods*. The fossil forms called *Bellerophon* and *Maclurea* are considered to have belonged to *Heteropods* of considerable size. In Fig. 207 is shown one of the *Carinarias*, swimming upon its back. It is so transparent that the intestinal canal can be seen terminating in the dorsal gill chamber, and protected by a curved shell (*s*); on the ventral surface is seen the fin-shaped

disk, converted into a swimming organ, and furnished with a sucker at *f*.

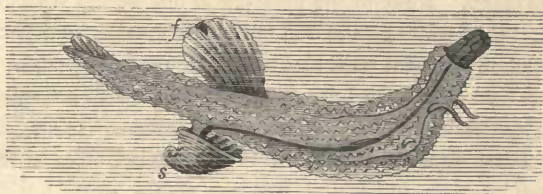


Fig. 207.

D. *Lamellibranchs*.—The Lamellibranchs form, with the Brachiopods, the Bivalve shells of Linnæus; and are sometimes called *Acephals*, because they have no heads; they are called Lamellibranch, from the arrangement of their gills in leaves, as is well seen in the so-called “fringe” or “beard” of the oyster. The body of these Mollusks is more or less completely enveloped in the loose mantle which surrounds it, and secretes the bivalve shell; frequently this mantle has an opening in front through which the foot, Fig. 208, *f*, emerges, and another opening



Fig. 208.

behind, through which the *branchial* and *anal* siphons are extruded (*b*, *a*); the lower of these siphons admits a constant current of water into the cavity of the loose mantle; this water passes forward, over the gill plates, and reaches the mouth, which is placed in front, above the foot *f*, and is then carried backwards along the dorsal surface, receiving the anal excretions behind the hinge; and finally leaves the mantle by the efferent or anal siphon, marked *a* in Fig. 208; thus the same current of water that oxidates the blood in the gills carries the particles of food

on which the bivalve subsists, to the mouth, and circulating again backwards, serves as the sewer that carries off all the impurities of the system. Many of the bivalves do not possess siphons, but the current of water sets in and out of the mantle, and performs a circulation identical with that which occurs in Fig. 208.

The Lamellibranchs have always a heart with a single ventricle ; sometimes two such hearts remote from each other (*Arca*) ; in the latter case, the two hearts fulfil the same office at the different sides of the body, and, like the single heart, are always *arterial*, receiving the blood from the gills, instead of forwarding it to those organs ; there are sometimes two auricles in the heart (*Anodon*), and sometimes only one, as in the *Oyster*. The *cerebral*, *pedal*, and *splanchnic* pairs of ganglions are always present ; presiding over special sensation, locomotion, and organic life, respectively. The symmetry of the Lamellibranchs is a right and left hand symmetry, for the right and left halves of the mantle each secrete a distinct shell, and in this respect their symmetry is essentially distinct from that of the Brachiopods, in which the mantle lobes correspond to the anterior and posterior regions of the body, so that the valves of their shell are called dorsal and ventral, instead of right and left valves.

The natural families of the *Lamellibranchs* are grouped together, on two principles of classification ; according as they have, or have not, siphons ; and according to the shape of the line called the *pallial* line. This line is formed by the muscular fibres of the margin of the mantle, where it is attached to the shell ; if the margin of the mantle form a continuous line, as in Fig. 209 (*Cyprina*), the shell is called *integro-palliate*, and the animal that lived in it either had no siphons, or those siphons were not retractile ; if, on the contrary, the La-

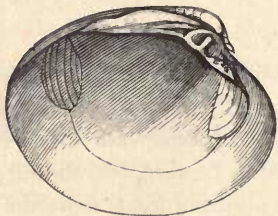


Fig. 209.

mellibranch possessed a retractile siphon, the margin of the mantle shows a *sinus* at its posterior rim, which marks the position of the muscular fibres employed to draw it back, and also measures approximately the length of the siphon itself: in such a case the shell is called *sinupalliate*, and the general form of the pallial line is shown in Fig. 210 (*Cytherea*).

The shell here figured is one of the *Venus* family, which is considered to be the most highly organised of the Bivalves. If we arrange the families of the bivalves according to their relationship and affinity to each other, setting out from the *Venus* family, we shall

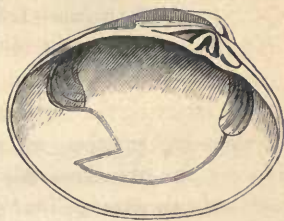


Fig. 210.

find that two distinct lines, or streams of relationship, carry us from the *Veneridæ*; in one direction, to the *gaping* shells and *boring* shells, which are related to the *Ascidian* Mollusks; and in the other direction, to the *Oysters*, which are related to the *Brachiopods*.

FIRST STREAM OF RELATED FAMILIES.

A. *Lamellibranchs with Sinupalliate Shells.*

1. *Veneridæ*—The *Venus* family.
2. *Mactridæ*—The *Mactra* family.
3. *Tellinidæ*—The *Telline* family (Fig. 208).
4. *Solenidæ*—The *Razor* shells.
5. *Myacidæ*—The *Gaping* shells.
6. *Anatinidæ*—The *Duck-bill* shells.
7. *Gastrochænidæ* } The *Boring* shells.
8. *Pholadidæ* }

SECOND STREAM OF RELATED FAMILIES.

A. *Lamellibranchs with Sinupalliate Shells.*

1. *Veneridæ*—The *Venus* family.

B. *Conchifers with Integro-palliate Shells.*a. *With Siphons.*

2. Cyprinidæ—The Cyprina family (Fig 209).
3. Cycladidæ— „
4. Lucinidæ— „
5. Cardiadæ—The Cockle family.
6. Tridacnidæ—The Clam shells.
7. Hippuritidæ—Altogether fossil.
8. Chamidæ— „

b. *Without Siphons.*

9. Unionidæ—The River Mussels.
10. Trigonidæ—The Trigonias.
11. Arcadæ—The Ark shells.
12. Mytilidæ—The Mussel family.
13. Aviculidæ—Wing shells.
14. Ostræadæ—The Oyster family.

E. *Brachiopods*.—These are marine *Mollusks*, better known by their representatives in the fossil than in the recent state; they have *gills attached to the mantle*, which is composed of a dorsal and a ventral lobe; and are furnished with two long spiral arms, which act as labial tentacles, and bring food to the mouth, which always lies at the base of the arms; the shell is bivalve, but the valves are, like the lobes of the mantle, *dorsal* and *ventral*, instead of right and left valves. These shells are called *Lamp shells* by the older Naturalists, from the hole in the apex of the *ventral* valve, which allows the passage of the pedicle by which it is attached to the rock, resembling the wick hole in an Antique Lamp. The general form of the *Lamp shells* is shown in Fig. 211, which represents a fossil species of *Terebratula*.

The mechanism by which the shell is opened in the *Brachiopods* differs widely from that used in the *Lamellibranchs*. The shell of *Lamellibranchs* is closed voluntarily by adductor muscles, and opens without effort by its ligament. In *Brachiopods*, however, muscles both open and close the valves, which

are thus independent of the elasticity of the hinge ligament.



Fig. 211.

The Brachiopods possess a "water vascular" system, furnished with two or four false-hearts, freely communicating with the surrounding medium, but having no connexion with the blood vessels, properly so called: this remarkable water-vascular system serves as an excretory channel, to convey away effete tissues, and the products of the reproductive organs; it is found, under variously modified forms, in most Mollusks, among which it seems to perform the office discharged by the kidneys in the other animals.

The Brachiopods are divided into the following families, most of the species of which are altogether fossil:—

1. Terebratulidæ—Lamp shells.
2. Spiriferidæ— „
3. Rhynchonellidæ— „
4. Orthidæ— „
5. Productidæ— „
6. Craniadæ— „
7. Discinidæ— „
8. Lingulidæ— „

F. *Ascidians*.—The *Ascidian Mollusks*, or *Tunicaries*, are so called from their resemblance to a leathern bottle or bag, with two apertures (Fig. 212), *o* and *a*, which give them the appearance of a two-necked jar. One of these apertures, called the oral

aperture, *o*, the so-called branchial sack, the entrance to which is often surrounded with a fringe of tentacles, admits a constant current of water, and leads into a large pharyngeal cavity; the gullet, stomach, and intestine, follow the pharynx in due order, and terminate in a chamber leading to the second aperture of the Ascidian, called the *atrial* or *anal* aperture, *a*, through which a stream of water constantly passes outwards. This water passes from the sides of the pharyngeal sack or gill chamber, by means of the water-vascular system, through the body walls, into the efferent or *atrial* chamber, from which it escapes again into the surrounding medium; and thus a perpetual circulation of water is established, carrying food into the stomach, oxidating the gills, and removing all the effete matters from the body tissues, in the manner of a kidney; which, even in the higher animals, is little more than a well constructed blood filter.



Fig. 212.

The Ascidians possess a distinct heart, of very simple construction, for it consists only of a muscular tube, without valves, and open at both ends. This heart behaves in a manner elsewhere unknown in the animal economy, for it works at regular intervals, alternately in opposite directions, forming, literally, a tidal circulation, in which the two ends of the heart are alternately venous and arterial.

All the Ascidians possess one nervous ganglion placed in front of the oral aperture.

G. Polyzoans.—The *Polyzoans* are well known to geologists as the so-called *Lace Corals*, and to sea-side collectors, as the *Sea Mosses*; they are minute social Mollusks, living together in communities, the common frame-work of which resembles seaweed of a horny constitution. One of the commonest of these Mollusks is shown in Fig. 213, which represents the *Flustra*, or *Sea Mat* of the British coasts. On examining the

Alustra with a lens, its surface is found to consist of a great number of symmetrical cells, placed close to each other, like those of a honey-comb; and each of these cells is found to be occupied by an individual mollusk, which was formerly regarded as a Zoophyte, but which is now well known to be much more highly organised than any Zoophyte.



Fig. 213.

The Polyzoans have long tentacles, furnished with vibratile *cilia*, which surround the mouth, and carry towards it a constant stream of water; they have an intestinal canal folded back upon itself, so as to open externally near the mouth; and between the oral and anal apertures the solitary nerve ganglion is placed; the anterior part of the Polyzoan is retractile within the posterior by inversion. The general structure of the individual Polyzoan is shown in the magnified Fig. 214, which represents the *Plumatella*, one of the fresh water Polyzoans.



Fig. 214.

No heart has yet been found in the Polyzoans, the results of digestion seeming to pass directly through the walls of the intestine, and to become mixed with the perivisceral fluid.

5. **Radiates.**—The Invertebrate animals, according to Cuvier, are divisible into three groups—*Articulate*, *Molluscan*, and *Radiate*—into which last group were thrown by Cuvier all the invertebrate animals that are neither articulate nor molluscan.

In the Radiate animals a special nervous system is not always present; when found, it appears as a ring surrounding the mouth, from which ring, nerves proceed like rays, to the circumference of the body. Among the Radiates, Cuvier admits that there are included some forms that cannot be called Radiate in any proper sense of the term; "the lowest families," he says, "present only a sort of homogeneous, sensitive, and mobile pulp." These lower forms, which are non-radiate, have, by common consent, been thrown into a separate group, called Protozoan; and the group of Radiates now contains only such animals as present the typical Radiate structure. It is divided into two minor groups—

A. The Echinoderms.

B. The Cœlenterate Animals.

Professor Huxley and other naturalists would remove the Echinoderms from the Cœlenterates, and place them with the Scolecid worms, with which they show many affinities in their earlier stages of growth; it is more convenient, however, for the purposes of an elementary work, to leave the Echinoderms among the Radiates of Cuvier.

A. *Echinoderms*. This name was originally given, after Aristotle, to the *Sea Urchins* only, but is now extended, to embrace the *Sea Stars*, *Sea Cucumbers*, and others. They form an exceedingly natural class, and may be readily distinguished from all other animals.

They are characterised by an intestinal canal, hanging free in the cavity of the body, usually long and tortuous, or furnished with lateral cæca when it is short.

In all the adult Echinoderms there exists a ring-like or polygonal ganglionic cord of nerves surrounding the mouth, and sending filaments to the locomotive organs.

Locomotion is effected in many Echinoderms by a peculiar arrangement: if we examine, for example the under surface of

one of the rays of a *Sea Star*, we shall find a groove (Fig. 215), furnished with four rows of perforations, like pin holes, in alternate rows, through which small fleshy cylindrical feet can be extruded, at the pleasure of the animal; this groove is called the *Ambulacrum* by Linnæus, from a fanciful resemblance to a walk among trees, and the little feet are called *ambulacral* feet. These feet are hollow cylinders communicating internally with the water-vascular circulation, which is developed on a grand scale among the Echinoderms. The fluid can be forced from the water-vascular tubes into the ambulacral feet, or withdrawn at pleasure; and the animal progresses slowly by the alternate protrusion and retraction of these feet. The rows of feet are generally two or four in number. In addition to the other vessels of the ambulacral, or water-vascular system, a peculiar tube, called the *madreporic canal*, terminating in the *madreporiform tubercle*, is found in the Sea Urchins and Sea Stars. The *madreporiform tubercle* is shown in Fig. 216, a.



Fig. 215.

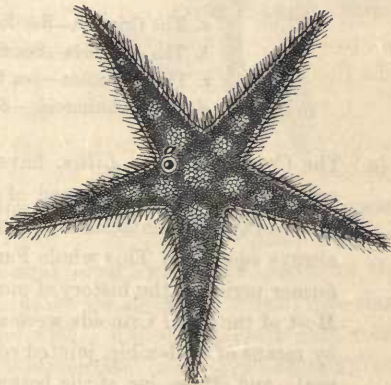


Fig. 216.

The Echinoderms enjoy a symmetry which is both *radiate* and *bilateral*, and may properly be named an *elliptically radiate* symmetry; while the lower forms of Radiates, among the Cœlenterate animals possess no bilateral symmetry, and may, therefore, be said to have a *circularly radiate* symmetry. In Fig. 216, a line drawn from the centre of the

Star rays to the *madrivoriform tubercle*, *a*, marks the plane of bi-lateral symmetry, or *axis of elliptical symmetry*; and in like manner, in Fig. 217, *c*, the line joining the mouth and anus



Fig. 217.

marks the axis of elliptical symmetry in the Urchin there figured (*Galerites*). The sexes are distinct in the Echinoderms, and the ovaries and testes are disposed in rays, opening in the Sea Urchins, by oviducts or sperm ducts, placed symmetrically round the anus, and equal in number to the typical number of rays.

The Echinoderms are divided into the following Orders:—

- a.* The Crinoids—Sea Lilies.
- b.* The Asteroids—Sea Stars.
- c.* The Echinoids—Sea Urchins.
- d.* The Holothuroids—Sea Cucumbers.

(*a.*) The *Crinoids*, or *Sea Lilies*, have a calcareous integument, or external skeleton, formed of symmetrical plates; with jointed rays, or tentacles surrounding the mouth, which is always *superior*. This whole Family belongs rather to the former period of the history of our globe than to the present. Most of the fossil Crinoids were attached to the sea bottom, by means of a flexible, jointed column (Fig. 218) (*Apiocrinus*); and others lay at the bottom, without being attached (Fig. 219) (*Saccocoma*); and it is remarkable that the fixed forms occur earliest in Geological history. There are two living forms of Crinoids, *Pentacrinus* and *Comatula*, of which the first is fixed, and the second is free; but it was ascer-

tained by Mr. Thompson, that in its earlier stages, *Comatula* is fixed like *Pentacrinus* to the solid rock; thus the history of the development of the *Crinoids* on the globe follows the order of development of the individual.

(b.) The *Asteroids*, or *Sea*

Stars have a depressed, free body, multangular or radiate, with a leathery or calcareous integument; mouth central, *inferior*.

The *Asteroids* are divided into *Ophiurids*, or Brittle Stars, and *Asterids*; the

Ophiurids have arms distinct from the disk (Fig. 220).

The *Asterids* have the arms confounded with the disk (Fig. 216), and are generally fur-

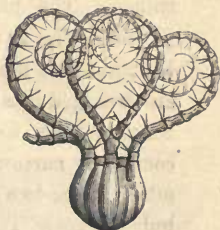


Fig. 219.



Fig. 220.



Fig. 218.

nished with a madreporiform tubercle on the dorsal surface, surrounded by a row of calcareous nipples. In most of the *Asterids* five arms occur, which is regarded as the typical number; but there are species in which rays from four to thirty are met with. The *Asterids* are very voracious, and act as sea scavengers; they glide rapidly from place to place, by means of their ambulacral feet, and feed principally on Mollusks, which they are said to paralyse by means of the juices of their everted stomachs.

- (c.) The *Echinoids*, or *Sea Eggs*. Body subglobose, or depressed, without radiant lobes; mouth and anus distinct, and mouth *inferior*; integument calcareous, beset with moveable spines. The plates of the *Echinus* (Fig. 221) are either pentagonal or hexagonal, and are arranged in a series of ten zones or *lunes*, five of which, commonly narrower than the others, have two rows of ambulacral pores, through which the feet are protruded, as already described. Around the *anus* are placed five apertures (sometimes only four), which are the outlets of the oviducts or sperm ducts; and these outlets are situated in as many calcareous plates, of which one, larger than the rest, corresponds to the madreporiform tubercle of the Sea Stars, and gives admission to the water supply of the ambulacral system. The moveable spines, whose number increases with age, work by a ball and socket joint on tubercles placed in meridian rows upon the surface of the shell. The mouth of the *Sea Urchins* is furnished with five teeth meeting in a point, which grow continually from behind, like the teeth of the *Rodents*; these teeth are worked by an apparatus of forty distinct muscles, and by means of them the animal nibbles at and swallows its food. They were first noticed by Aristotle, and are called by Naturalists *Aristotle's Lantern*, quite erroneously, for it was the entire shell of the Sea Urchin that Aristotle compared to a lantern, and not its masticating apparatus. He says, "the *Echinus* is not continuous as to its surface, but is like a lantern without a skin stretched over it," alluding apparently to the pin holes for the ambulacral feet, which are easily seen in the empty shell, because they admit the light.



Fig. 221.

(d.) The *Holothuroids*, or *Sea Cucumbers*, have a free, cylindrical body, covered by a leathery skin, secreting occasional calcareous particles; mouth surrounded with retractile tentacles; anus terminal, opposite to the mouth. In the most typical of these soft-bodied Echinoderms, the analogy to the other Echinoderms is remarkably shown by the pentagonal section of the cylindrical body, and by five longitudinal rows of ambulacral feet; in others, as in *Holothuria* (Fig. 222), the suckers are scattered either in rows or irregularly over the body, and the radiate structure almost lost, but still shown in the twenty radiating tentacles that



Fig. 222.

surround the mouth. The Siphon worms (Fig. 193) are placed by many naturalists among the Echinoderms, and evidently form a link between this group and that of the ringed worms; the analogies of the Echinoderms and Scolecid worms are so numerous that Huxley has proposed to unite them together with the ringed worms into one province, distinct from the *arthropod articulatae*, and to be called *Annuloida*.

B. *Cœlenterates*.—The *Cœlenterate* Radiates are so named from their want of a perivisceral cavity, distinct from the digestive canal and its processes (κοιλέντερα). They are composed essentially of an outer and an inner layer, or integument, both of which are furnished with vibratile *cilia*. Many of them, also, possess the property of secreting peculiar *threads*, which produce stinging effects on the animals in contact with them. They have mostly tentacles placed round the mouth, with which they seize their prey; and in a few of the more highly organised, traces of nervous system are said to occur. In some the sexes are distinct, while others produce ova and sperm, and are capable

also of reproduction by budding. With the exception of two freshwater genera, all the Cœlenterates are marine.

They may be conveniently divided into two classes—

a. Actinozoans.

b. Hydrozoans.

- (a.) *The Actinozoan Radiates* are Cœlenterate animals, in which the inverted wall of the general *digestive sack* is separated from the general wall of the body by a wide space, subdivided into chambers by a series of vertical partition, on the faces of which the ovaries, or sperm cells, are developed (Fig. 225). To the *Actinozoa* belong, among others, the *Sea Anemones* (Fig. 223), and *Coral Polyps* (Fig. 224), which differ only, as the shelly Gasteropods and Slugs differ, by the faculty of secreting carbonate of lime, which the Coral polyps do internally, as the shelly Gasteropods do externally.

The *Sea Anemone* (Fig. 223), may be regarded as the type of

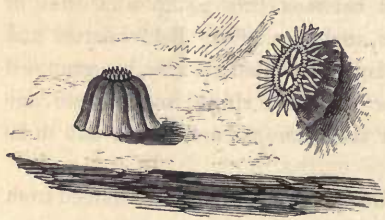


Fig. 223.



Fig. 224.

the Actinozoans; it is of a soft, leathery consistence, and attaches itself by its base to the rock, its mouth being placed opposite to the base, and facing the sea water, which furnishes it with food. Numerous tentacles, arranged after Nature's fashion, alternately in concentric circles, surround the outer margin of the voracious mouth, which readily swallows whatever soft edible substance is placed within its reach; and these tentacles, with their thread cells, are even capable of seizing and of paralysing an animal as

highly organised as a *Tadpole* that unhappily strays inside their magic circle. The mouth in the *Sea Anemone* is not circular, but elliptical, the major axis of the ellipse being well marked by a white diameter, or ray, that crosses the disk, and forms one of the prominent body walls of the animal. This remarkable diameter declares the elliptical symmetry of the Actinozoan, and shows its relationship to the Echinoderms, the highest form of Radiate animals.

A transverse vertical, or meridional section of a *Sea Anemone*, exhibits the structure shown in diagram 225; here we observe two concentric tubes, the outer being formed by the *body wall*, and the inner formed by the boundary of the *digestive sack*. The annular space between these cylinders is divided by a

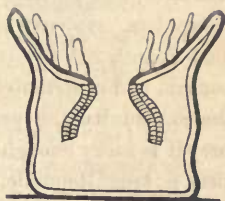


Fig. 225.

number of radiating partitions, arising at definite intervals, from the inner surface of the body wall. Some of these radiating partitions unite completely the body wall and stomach wall, and act as mechanical supports to both; while others of the partitions traverse only a portion of the distance between these concentric tubes; to these imperfect partitions, which are always of more recent growth than the primary or perfect radiating partitions, are generally attached the ovaries, or testes, of the *Sea Anemone*.

The *Coral Polyp* differs from the *Sea Anemone* only by the property of depositing or secreting a calcareous skeleton in its radiating partitions, and body and stomach walls; the skeleton thus secreted (Fig. 224), survives the soft part of the Cœlenterate animal that produced it, and thus remains as a coral, embedded in the rock, for the study of future geologists.

In this manner naturalists have been enabled to compare together the Actinozoans with calcareous skeletons belonging to all epochs of the history of the globe.

The Actinozoans are divided into the following Orders :—

1. *Zoantharia*.
2. *Alcyonaria*.
3. *Rugosa*.
4. *Ctenophora*.

The *Zoantharian* Actinozoans comprise the *Sea Anemones* and *Corals* already described, many of the latter being composite in character, and consisting of numerous individuals forming one Polypidom, as shown in Fig. 226. Each individual Zoanth has the true structure of the Actinozoan, and contributes to the general welfare of the community the products of digestion of any prey it is lucky enough to capture. They constitute a true Republic, in which each citizen, whether consciously or not, is compelled to support the general state, by which he himself exists.



Fig. 226.

In the Zoanths, the tentacles and radiating partitions are disposed in multiples of the number six, and, more rarely, of the number five.

The *Alcyonarian* Actinozoans contain the *Sea Pens* (Fig. 227), the *Organ pipe Corals*, and the *Gorgonias*; they are characterised, like the *Rugose Corals*, which are exclusively fossil, by having their tentacles and radiating partitions multiples of the number four, instead of the numbers five or six, which prevail in the *Zoanths*.



Fig. 227.

The *Ctenophore* Actinozoans have, as their name implies, comb-shaped meridional lines drawn upon their globular, or subglobular bodies (Fig. 228 *a, b*). They are transparent, often luminous, oceanic delicate Actinozoans, and swim by means of the *cilia* attached to their

meridional fringes. In Fig. 228, *a*, is represented the *Beroe*, one of the best known of the luminous Actinozoa, found in countless

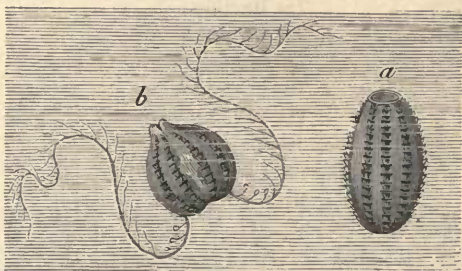


Fig. 228.

myriads in the Northern Seas, where it forms the food of numerous Cetaceans and other animals. These Ctenophores present numerous variations of forms, but are all comprised within the anatomical limits that define the Actinozoans, and distinguish them from the *Hydrozoan Radiates*.

- (*b.*) The *Hydrozoan Radiates* are *Cœlenterate* animals, in which the digestive sack and body cavity form one continuous cavity; and the reproductive organs are external. A diagrammatic view of this structure is given in Fig. 229, which represents the ideal *Hydrozoan*, just as Fig. 225 represents the ideal *Actinozoan*. The body of the *Hydrozoan*, like that of the *Actinozoan*, is formed of an outer and an inner membrane, or integument, the tentacles being composed of prolongations of both. *Thread Cells* are developed in the *Hydrozoan* from the inner layer, and possess the same properties as in the *Actinozoan*, only in a less marked degree. They are as voracious as the *Actinozoans*; and, like these, are either unisexual or hermaphrodite.

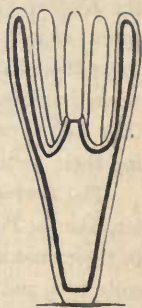


Fig. 229.

The Hydrozoans are divided by naturalists into the following groups :—

1. The Hydridæ.
2. The Corynidæ.
3. The Sertularidæ.
4. The Calyciphoridæ.
5. The Physophoridæ.
6. The Medusidæ.
7. The Lucernaridæ.

The *Hydridæ* include the freshwater *Hydra* (Fig. 230), which first attracted the attention of naturalists to the peculiarities of the Hydrozoans. The *Hydra* consists of a long tube, enclosing the stomach, and terminated by a mouth surrounded by seven tentacles ; and its ordinary mode of reproduction is by budding, as shown in the figure ; when removed from the water, the *Hydras* appear as minute specks of jelly, but quickly recover their true form on being again immersed in the water ;

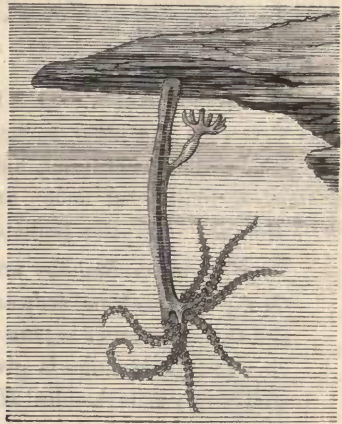


Fig. 230.

they feed voraciously, and seem to possess the power of benumbing their victims by means of thread cells, like the Actinozoans.

The *Sertularidæ* are Hydrozoans, composite in their character, like the Polyzoan Mollusks, but, of course, much less complex in their anatomical structure. They are well known to seaweed collectors, and are often confounded with the Polyzoans. One of the best known of our native forms is shown magnified in Fig. 231. Each of the minute cells in this *Sertularian* protects a distinct Polyp, having the simple structure of the *Hydra*, and the

food it consumes is digested, not only for its own benefit, but also for that of the whole community.

Of the seven divisions of Hydrozoans, the *Hydridæ* and *Sertulariæ* just noticed, and also the *Corynidæ* (*Club Hydras*), and *Lucernariæ* (*Lantern Hydras*), are sessile; while the remaining groups, the *Medusidæ*, the *Calyciphoridæ*, and the *Physophoridæ*, are free swimmers, and oceanic in their habits. Of these, the best known are the *Medusidæ*, illustrated in Fig. 232. These beautiful animals, well known as *Sea Nettles*, from their stinging properties, abound

in almost every sea, and sometimes attain a very considerable size. The *Medusa*, or *Sea Nettle*, or *Sea Blubber*, consists essentially of an inverted hemisphere, or swimming calyx, from the centre of the under surface of which the digestive sack is suspended with its mouth downwards. The Swimming Calyx is provided with a complicated system of canals, and varies considerably in form among the different species of *Medusidæ*.

6. **Protozoans.**—The *Protozoans* are the lowest forms of animal life, and are properly excluded from the Radiates, which

they resemble in no feature of their structure. They may be defined by negative rather than by positive qualities. In none of the Protozoans have a nervous system and organs of sense been



Fig. 231.

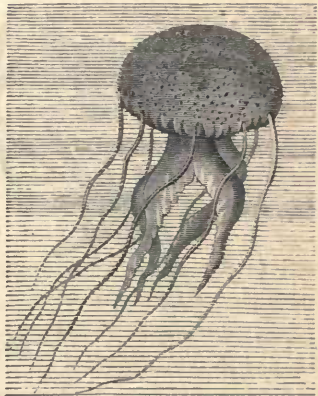


Fig. 232.

discovered, and in many of them the existence of a digestive apparatus has yet to be ascertained. Most of the *Protozoans* are reproduced by vegetative budding, and they are essentially aquatic in their habits, and none of them, except the *Sponges*, attain an appreciable size.

The Protozoans are divided by Naturalists into the following groups :—

- A. Rhizopods.
- B. Sponges.
- C. Gregarines.
- D. Infusories.

A. *Rhizopods*.—The *Rhizopods* are so named from the faculty they all possess of shooting out, apparently at will, long slender processes called *pseudopodia*, from various parts of the soft, gelatinous, uniform mass of which they are composed. These pseudopodia are shown in Fig. 233, which represents one of the common-

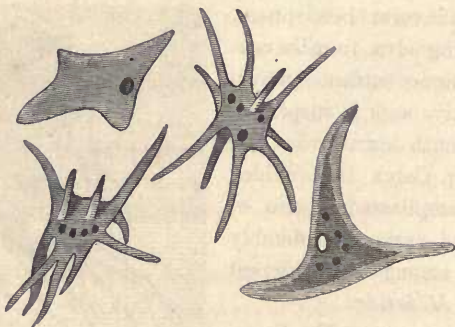


Fig. 233.

est forms of these Protozoans (*Amæba*). The *Amæba* extends its pseudopodia around any small digestible substance with which it comes in contact, and absorbs nutriment from it by simple imbibition, or *endosmose*, like the rootlet of a plant.

The Rhizopod, figured at Fig. 233, is composed altogether of

soft parts, and possesses no definite shape ; many of the Rhizopods, however, secrete highly symmetrical skeletons, either of carbonate of lime, or of silica, and are well known to Geologists from their abundance in certain strata. These Rhizopods are called *Foraminifers* and *Polycystines*, and are found in great numbers, forming the floor of the ocean in deep seas.

The *Foraminifers*, Fig. 234, are usually covered by a calcareous shell, consisting of an aggregation of small cells communicating with each other by means of minute apertures. During life, all these cells and their communicating canals are filled by the uniform pulpy mass of the Rhizopod, which protrudes its hair-like processes externally, exactly in the same manner as the soft-bodied Rhizopods. Most of the recent Foraminifers are microscopical in size, while many of the fossil forms attained considerable dimensions.

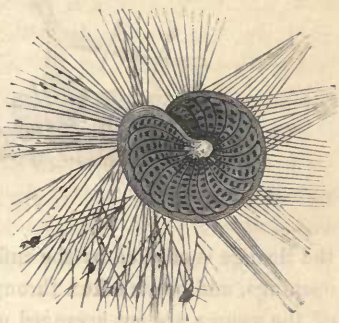


Fig. 234.

The *Polycystine* Rhizopods are smaller than the Foraminifers, and differ from them in secreting a siliceous instead of a calcareous skeleton. Their shells are remarkable for the exquisite beauty of their forms.

B. *Sponges*.—The *Sponges* were recognised by Aristotle as true animals, and as possessed of sensation, although they resembled plants in some respects. They are well known by their skeletons, which are composed of fibres of a horny texture, strengthened by needles, or *spicula*, of siliceous or calcareous matter ; and this framework is so connected together, as to form a kind of fibrous skeleton. During life, the skeleton or sponge is coated by a gelatinous, homogeneous, substance, like that forming the mass of the living Rhizopods, and furnished with cilia, which, by their incessant

vibratile movements, cause a continual circulation of water through the canals that traverse the substance of the Sponge. On examining a Sponge, it will be seen that these canals (Fig. 235) communicate with the external water, directly or indirectly, by many minute, and a few larger openings. The water circulation in

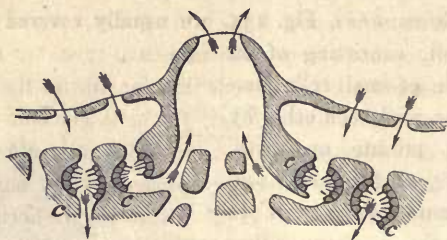


Fig. 235.

the Sponge is effected by the influx of water through the smaller openings, and by its efflux through the larger apertures. The cilia of the sponge are not arranged uniformly along the walls of the canals, but occupy definite positions in small spherical cells at intervals, marked *c, c, c, c*, in Fig. 235. These vibratile centres may be regarded as the individuals that compose the complex sponge, which has been compared by Huxley to “a kind of subaqueous city, where the people are arranged about the streets and roads, in such a manner that each can easily appropriate his food from the water as it passes along.”

C. Gregarines.—The *Gregarines* are considered by naturalists as the simplest in structure of all animals. They occur as Entozoans in the Articulates, such as Cockroaches and Earth worms; and are utterly destitute of either mouth or intestines, living altogether by the imbibition of the juices that surround them. They consist essentially of a delicate elongated sack, filled with a homogeneous granular jelly, or *sarcode*, and enclosing a small, and more solid nucleus. Less is known of these obscure beings than of any other animals.

D. *Infusories*.—The *Infusories* are microscopic animals, much smaller than the Rotifers, and constituting for the most part the food of the latter ; they swim about by means of cilia covering the surface of their bodies ; and have been proved to possess an organisation considerably in advance of that of Rhizopods, Sponges, or Gregarines ; for they are found to contain both a mouth and an anus opening near it. The mouth leads into a gullet, open at the bottom, and not leading into a stomach or intestinal tube, but losing itself in the soft central mass of sarcode that constitutes the main body of the Protozoan ; in like manner, the anus commences vaguely in the same soft sarcode, and drains it, without the aid of a regular intestinal tube, of its excretory products. It has been also ascertained that these microscopic Infusories are hermaphrodite, each individual producing both ova and sperm cells, by contact of which a true generation is effected, in no essential respect differing from what occurs among the higher animals.




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